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Research Article

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Impact of Irrigation Systems Use in Agriculture Farming in Rwanda: A Case Study of Kagitumba, Nasho and Muyanza Schemes.

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ABSTRACT
Agriculture remains an important economic sector in many developing countries. It is a source of growth and a potential source of investment opportunities for the private sector. Irrigation, therefore, currently plays a less significant role in African agriculture compared to other regions, as Africa's irrigated cultivated land is much lower than the world average. This research study investigated the impact of irrigation system use in agriculture farming in Rwanda. A multi-stage sampling method was employed, whereby the Nyagatare, Kirehe and Rulindo districts, and three irrigation schemes such as Kagitumba, Nasho and Muyanza were first purposely selected. Finally, a simple random sampling was used to obtain a total sample size of 240 maize farming households, within these three irrigation schemes. The findings indicated that land size was significantly and positively associated with the water pump use. The water pump and sprinkler irrigation system use and farm income were significantly and positively correlated. The water user's association's membership and the water pumper drip and sprinkler irrigation systems were significantly and positively correlated. The findings of this research revealed that factors namely family size, education level, fertilizers, irrigation system, farming experience are statistically significant to influence productivity of maize crops at these irrigation schemes. In addition, the results of cost benefit and margin analysis indicated that the Net Farm Income (NFI) per ha at Nasho schme site was largest followed by Kagitumba and Muyanza scheme site was the lowest. However, the benefit cost ratio was the highest (2.3) at Kagitumba site, suggesting that one-dollar of investment at Kagitumba irrigation scheme generates 2.3 dollars of revenue. Some factors in this study were statistically and significant to influence the farmers' willingness to pay for irrigation water in study areas. After the findings, the researcher suggested that farmers should be encouraged to better use agricultural inputs, high attention should be made on infrastructures in order to sustain and maintain them in long run, farmers should be encouraged to pay for irrigation water, public and private sector should increase investment and expand the drip and sprinkler irrigation system where possible in country.
Keywords: Economic Analysis, Impact, Irrigation System, Agriculture Farming, Scheme.

INTRODUCTION
Agriculture remains an important economic sector in many developing countries. It is a source of growth and a potential source of investment opportunities for the private sector. Two-thirds of the world's agricultural value added is estimated to be created in developing countries (World Bank, 2008).
In Sub-Saharan Africa, it still provides a relatively large share of the gross domestic product (GDP) in many countries but productivity in the sector lags considerably behind that of other continents, as well as the region's potential. On average, about 65% of Africa's labour force is employed in agriculture activities, yet the sector accounts for only about 32% of GDP, reflecting relatively low productivity and subsistence farming. In Africa, most agricultural land is rain-fed and subject to erratic rainfall and recurrent droughts, leading to low agricultural sector performance. This includes low resilience of rural people to climatic effects, irregular

production and low productivity, low intensification and crop diversification, and weak value chain and market development (Fethi Lebdi, 2016).

Rwanda is a hilly country where most of the cultivation area is on hillside with an incline of more than 60% slope (MINAGRI, 2010). Given that, 90% of domestic cropland is on slopes, more efforts deployed in land management to improving land productivity and stability (MINAGRI, 2019). The agriculture sector is the main economic activity in Rwanda where 64% of the working population are employed in Agriculture. Agriculture GDP represents around a third of the National GDP and currently stands at 24% (MINAGRI, 2010). Smallholder agriculture is argued to remain important for economic development and poverty reduction in developing countries, but its development is challenged by the need for institutional innovations to overcome market failures (World Bank, 2008).

Given the predominance of agricultural livelihoods among poor rural households, this agenda will often have a strong agricultural orientation, with a focus on improving sustainability and resilience in agricultural practices. However, the agenda also needs to be relevant to different types of livelihoods that sometimes exist within a single household (MINAGRI, 2011). Modernizing and increasing productivity of Agriculture and livestock is one of the priority areas of the Government strategy for transformation (2018-2024) (MINAGRI, 2019).

Despite the importance of agriculture sector and the Government strategy for transformation (2018-2024), there is a huge low productivity of lands resulting from excessive use of land and low application of inputs including fertilizers, improved seeds pesticides; lack of stable irrigation system, difficulties to get access to agricultural credit, conservation of water and soil not integrated in agriculture and livestock, shallow knowledge about water management by the farmers, agricultural mechanization nearly absent and less operational, and marshlands badly and less exploited (MINAGRI.,2004) and (Tetteh Anang, B,2015).

Therefore, this require an effort of introducing new varieties, disease mitigation strategies as well as improving farmers' knowledge and skills to support specialization, intensification, diversification, and value addition is critical. In addition, reinforcing advanced technology will trigger increased production as well as facilitating in copping up with climate risk mitigation strategies (MINAGRI, 2004).

Agriculture has tremendous potential to reduce poverty and create employment for the rural poor since most are employed in it. However, this cannot be achieved without improving the agriculture water resources use. Given that agriculture is largely rain-fed, irrigation water has become a very crucial resource in agricultural production, and poverty reduction. Poverty reducing impact of irrigation is substantial as evidenced in many Asian countries. For example, about 35-40% of cropland in Asia is irrigated and poverty reduction in the 1970s was substantial (Hussain & Hanjra.,2003).

Despite rapid economic growth in Africa over the past years, the performance of agricultural sector is low and hunger continues to be a risk, in particular in the Horn of Africa and Sahel region. Rural vulnerability, low resilience to climatic effects and poverty are still deep in rural areas and nutrition is poor. Agricultural transformation is needed in Africa to address these challenges and irrigation is one pillar to contribute to such transformation (Fethi Lebdi, 2016).

Rwanda is very rich in surface water, yet crop yield and crop productivity consistently suffer from a lack of irrigation water specifically eastern region during the growing season. The factors considered in using irrigation as a production strategy in Rwanda has been different from many countries mainly because of geographical diversity, water availability and financial constraint. Irrigation schemes has allowed farmers to move from rain-fed agriculture to diversified high value crops hence resulting to increased cropping intensity and land productivity. The country has registered 63,742 ha under irrigation - including 37,273 ha of marshlands, 8,780 ha of hillsides and 17,689 ha of small-scale irrigation (MINAGRI, 2020).

In Rwanda, agriculture provides rural employment, guarantees food security, and drives economic growth. Therefore, successive governments have attached importance to agricultural and rural development through a series of development programs and agricultural reforms. Water is a vital economic resource especially in agriculture, as it plays a crucial role in the fertility of agricultural lands (Davivongs, V *et al*, 2012). In addition, accessibility to water resources contributes to improving the livelihoods of small-scale farm households (Kitchaicharoen *et al*, 2008).

Water scarcity has become a major issue for both policy makers and water users. In fact, agriculture sector is more prone to water scarcity. Adoption of modern irrigation technology can be an appropriate strategy to overcome the effects of water scarcity (Koundouri *et al*, 2006). In developing country including Rwanda, irrigation can be considered as a strategy of poverty reduction through intensive agriculture (Smith, 2004). Nevertheless; for proper management and development of irrigation system, there must be a sound coordination between local institution and government agency (Ostrom, E, 1992).

The traditional system of irrigation comprises of the use of either rope and buckets to lift and distribute water from shallow open wells or watering cans to lift water from streams. Although the low capital requirement of these traditional technologies makes them advantageous and affordable, their low delivery capacity and labor-intensive nature make them highly unfavorable to African production conditions (Kamara, 2004).

Such traditional methods of irrigation like flood, level border, and furrow requires more water in short amount of time. Since those technologies are based in the gravity

that results in non-uniform distribution of water. Whereas, for some modern technologies, such as drip and sprinkler irrigation, comparatively less amount of water is required over long time and the distribution of water is uniform by maintaining a level of pressure in water delivery system (Green,1996).

An irrigation scheme is a systematic approach to managing water in the farmland whereby the water is provided to and channelled away from the farmland, and includes the conservation of water for dry seasons and ecological maintenance. The ultimate goal of an irrigation scheme is to enhance the economic performance with minimal water and energy consumption (Samian *et al.*, 2014; Pandy., *et al;* 2000, and Panda *et al*., 2004).

Irrigation water is applied to ensure that soil moisture is sufficient to meet crop water needs and thus reduce water deficit as a limiting factor in plant growth (Van-Averbeke, *et al.*, 2011). Irrigation technology allows for the control and distribution of water to meet varying needs within a water system, such as agricultural, industrial, and household needs (Gregg, N. S.; 2008, Lenton, R.; Muller, M. 15). Irrigation is generally defined as the application of water to the land for the purpose of supplying moisture essential to plant growth. Irrigation is intended to augment the water supply from rainfall Mutsvangwa, T., & Doranalli, K., (2006) defined irrigation as the cultivation of land through the artificial application of water to ensure double cropping as well as steady supply of water in areas where rainfall is unreliable. There are wide variations in the proportion of irrigated agricultural land in the developing world, with 37% in Asia, 15% in Latin America, 6% in Africa and 4% in Sub-Saharan Africa (FAOSTAT, 2012). Irrigation, therefore, currently plays a less significant role in African agriculture compared to other regions, as Africa's irrigated cultivated land is much lower than the world average.

Low levels of irrigation in Africa are as a result of high irrigation investment costs, perceived failures of past irrigation projects, limited government commitment, and poor rural infrastructure, and fragmented farmers, and crops with low water requirements (You *et al.,* 2010). Irrigation schemes have proven to be a viable and attractive option for rural farmers in developing countries. He further asserted that returns from irrigated farming even on tiny plots could greatly exceed returns from rain-fed production. In many developing countries, irrigation schemes were counted on to increase production, reduce unpredictable rainfall and provide food security and employment to poor farmers (Burrow, 1987). It enables farmers to earn an income, which enables them to meet some of their basic needs.

There are some interrelated mechanisms by which irrigated agriculture can increase particularly increasing production and income, and reduced food price, that helps poor households meet the basic needs and improve welfare, protecting against the risks of crop loss due to erratic, unreliable or insufficient rain fall, promoting greater use of yield enhancing farm inputs which creates additional employment, which together enables people to move out of the poverty cycle.

Compared to furrow systems, drip irrigation can substantially improve water use efficiency (WUE) by minimizing evaporative loss of water and maximizing capture of in-season rainfall by the soil profile (Dandedjrohoun, 2012). The main disadvantage of drip irrigation systems is the cost of installation and maintenance. Historically, irrigation scheduling in drip irrigation systems has proved to be slightly more difficult than for other irrigation delivery methods nevertheless, drip irrigation can help satisfy the demands associated with increased pressures of growers to increase WUE and maximize production (Oladeji *et al.*, 2015).

However, there are a number of studies in different countries that show evidence that irrigation schemes have served as the key driver behind growth in agricultural productivity and increasing household income and poverty alleviation (Lipton, 2003).

There is a need to prioritize irrigation development in Rwanda not only because of the existence of agricultural water resources, but also because of the high value of irrigated agriculture in the country and the large number of rural poor that could benefit from high productivity as a result of irrigation investment. These schemes helped in reducing rural-urban migration by offering rural population an alternative source of employment and income. Food security is likely to increase in households practicing irrigation farming. This study was mainly focused on analysis of the impact of small-scale irrigation system use in agriculture farming in Rwanda.

MATERIALS AND METHODS

Description of the Study

This study focuses on the three districts namely Kirehe, Nyagatare and Rulindo of Eastern and Northern Province respectively. Kirehe District is one of the seven districts making up the Eastern Province. It is made up of 12 administrative sectors, 60 cells and 612 administrative villages. Kirehe District extends over a total area of 1,118.5 Km^2 with about 164,012 male and 176,971 female inhabitants equalling to 340,983 of its total population according to the newly provisional results released by the National Institute of Statistics of Rwanda (NISR, 2014). The Economy of Kirehe district is based on agriculture and livestock, which is at least 90% of the population. It is characterized by a low altitude plain of more or less than 1,350 m of altitude. The District of Kirehe is characterized, in general, by lowly undulating hills separated by valleys some of which are swampy and boggy. This kind of topographical layout constitutes an important potentiality for modern irrigation system and mechanized agriculture.

The study area covered three irrigation schemes such as Kagitumba, Nasho and Muyanza locsted in the said above districts. Due to their mechanization and irrigation system, the annual crops cultivation was possible for all seasons. Umuvumba, Akagera Rivers and Muyanza

Dam are being the main source of irrigated water of those commend areas. In the eastern province, the water from the Umuvumba, Akagera Rivers basin were principally used for agriculture and household consumption purposes.

Sampling Technique and Sample Size

A field survey was carried out using a structured questionnaire to gather the quantitative data from the participating crops farming households in this study sites. In addition, observations, in-depth interview sessions, focus-group discussions, and key informant interviews were undertaken for the background and qualitative data. The population of interest constituted by farmers growing crops in thess three irrigation water schemes. A multi-stage sampling was used, whereby the Nyagatare, Kirehe and Rulindo districts, and three irrigation schemes such as Kagitumba, Nasho and Muyanza were first purposely selected. Following this, stratified sampling was applied to categorize the farming households by the irrigation system: the water pump, drip and sprinkler. Finally, simple random sampling was used to obtain a total sample of 240 crops farming households, within which there are 106 farmers for water pump irrigation system, 40 farmers for drip irrigation system, and 94 farmers for sprinkler irrigation system farmers.

Data collected were analysed using descriptive statistics, cost benefit, gross margin, budgetary technique analysis and quantitative methods. Descriptive statistics such as percentage and frequency were used to analyse farmer's socio-economic characteristics to maize production. Multiple regression analysis was employed to identify the factors influencing irrigation system use and productivity of crops grown in area; cost benefit, gross margin and budgetary technique analysis were used to evaluate the profitability of using irrigation system in agriculture farming improved seeds, while difference in difference method was employed to compare the impact of three irrigation system on productivity of crops grown in those schemes. The gross margin technique is specified below:

$GM = TR - TVC$

Where:

GM = Gross margin, TR = Total Revenue from maize

TVC = Total Variable Cost utilized

Data Analysis

A process of cleaning, transforming, and modeling data to discover useful information for business decision-making. The purpose of Data Analysis is to extract useful information from data and taking the decision based upon the data analysis.

For this study, both quantitative and qualitative data analyses were applied. Descriptive statistics were used to describe the characteristics of the households by frequency, percentage, and standard deviations. Economic returns associated with the three irrigation technologies were analysed using the cost and benefit method where the F-test was employed to determine the statistical differences of the revenue and cost items among the variable irrigation schemes.

The functional form of the stochastic frontier production (or cost) model employed for this study is the Cobb-Douglas (C-D) functional form. This is because it is self-dual and therefore it allows for the estimation of both the production and cost functions. The efficiency estimates obtained by the methods described above are regressed on some farm and household specific attributes by use of the Tobit model.

RESULTS AND DISCUSSION

Demographic and Socioeconomics of the Respondent's Farmers

Table 1 shows the demographic and socioeconomic characteristics of the maize farmers involved in irrigation system (water pump, drip, and sprinkler) at Kagitumba, Naho, and Muyanza schemes.

The findings in table 1 indicated that (50.8%) of the respondent farmers (240 farmers) were male and 41.9% were female. The respondents' ages were classified into four age groups (table 1): less than 30; 31–40; 41–50, and above 51. Overall, the 46–51 age group constituted the largest proportion (35.4%), followed by the 31-45-plus (33. 8%), less than 30 (18.8%), and above 61 (12%) age groups. The findings showed that younger generations are currently abandoning agriculture farming due to the lack of initial capital and other support to enter the sector properly which in turn cause a huge lack of labor force and high urban migration. The respondents' years of maize farming experience were classified into five lengths of time. The findings of this study indicated that the overall, the 11–15 group had the largest number of respondents (30%), followed by the 6–10 (29.2%), 16–20 (16.6%), >5 (14.2%), and above 20 years (10%) groups.

The land sizes were categorized into five classes as shown in table above. The findings revealed that the majority of farmers have farm less than 1 ha represented by (43.3%) followed by the class ranging between 1.1-2 ha with (21. 7%), 2.1-3 with (14. 2%). The results indicated farmers with small land are concentrated in Muyanza site in Rulindo diatrict with less than 1 ha. While big farmers with big farm are highly located in Nasho, and Kagitumba sites in Kirehe and Nyagatare districts respectively. This implies that irrigation system is more utilized in eastern region rather than northern due to the lack of regular run fall. The study indicated that an increase in the land size influenced an increased probability of the water pump, dip, and sprinkler irrigation system used in maize farming in study areas.

The Factors Influencing Farmers to Use (Water Pump, Drip and Sprinkler) Irrigation System

A probit regression model was fitted using the binary dependent variable. The results of the model showed that the data fitted well (R-square equal to 0.7768; 0.7920, and 0.8587 respectively for Water pump irrigation system, Drip irrigation system, and Sprinkler irrigation system all of them with a p-value < 0.0001) as presented in table 2.

The water pump and drip irrigation system and age had a significant negative correlation with each other (β = -0.0735, p < 0.05), while this association was significantly positive between the sprinkler use and age (β = 0.207, p < 0.05). The findings showed that the young farmers were more receptive to the sprinkler irrigation system due to its ease of use, while their old farmers preferred the WP technology probably due to their familiarity with the motorized machinery and pumps as well as their great distance from the water source. Our support in-depth interviews indicated that the discontinuity of traditional irrigation system could lead a new generation of farmers shifting to using new technology especially drip and sprinkler due to its easier use and easily facilities from government.

Land size was significantly positively associated with the water pump use (β = 0.621, p < 0.01). Thus, an increase in the land size contributed to an increased probability of the use of drip and water pump irrigation system use in maize cultivation of the study area. The water pump and sprinkler irrigation system use and farm income were significantly positively correlated (β = 0.000, p < 0.01), which suggested that the increased income from the sales of maize contributed to the greater likelihood of the two-system utilization. On the other hand, the drip irrigation system was significantly negatively associated with farming income (β = -0.007, p < 0.01). Supported by, one study Gebregziabhe *et al*., (2014) noted that farming households with alternative sources of income exhibited a greater tendency to adopt modern irrigation technologies (e.g., the motor pumps). It was also supported by farmers revealed that farmers using water pump many times face some challenges especially expenses in terms of equipment, maintenance, and fuel.

The sprinkler and water pump use were significantly positively correlated with an upstream farmland location (β = 4.042, p < 0.01). On the other hand, the upstream location of farmlands was significantly negatively associated with the drip irrigation use (β = -0.387, p < 0.01). The findings revealed that despite the advantageous farmland location, the upstream maize farmers still deployed the sprinkler and water pump system to significantly irrigate their maize farms, giving rise to the downstream farmers' perceived unfairness of the water allocation. The farmers who are encourage away from the water resource may experience water shortages for agriculture farming, which in turn affect maize production.

The water pump utilization and the distance from the water source were significantly negatively correlated (β = -1.056, p < 0.01). This implies that a greater distance from the irrigation system meant a greater a lower chance of getting desired amount of water for irrigation due high requirement of materials. Moreover, a previous study of Aseyehegu *et al*, (2012) reported that distance had no influence on the water pump use in Ethiopia. Meanwhile, the relationships of the proximity to the water source with the drip and sprinkler system use were more and positively correlated. The water users' associations membership and the water pumper, drip and sprinkler irrigation systems were significantly positively correlated (β = 2.3745, p < 0.01).

Therefore, the registration of farmers into the water user associations plays an important role in terms of increasing the awareness of the issues of the lack of water and best exploitation of water resources and to allocate adequate water to members in the group, which influence positively water allocation efficiently and effectively. According to previous studies of Buyukcangaz, (2007) and Smith (2002), the establishment of water user associations and the transfer of responsibility for operation and maintenance of irrigation systems to the farmers plays an important role in encouraging users to adopt technologies for more efficient water use and increased crop production.

Factors Influencing Productivity of Irrigation System in Study Area

The factors influencing productivity of irrigation water were determined through OLS using STATA software with version 13.0. The results of OLS regression are presented in Table 3. The results in table 3 shows the model fits the data reasonably well (p-value < 0.0001 and R^2 of 0.83). This means that 83% of the variation in the dependent variable is explained by the explanatory variables.

Productivity of irrigation water is influenced by several factors in study area. In the study, social economic variables such as family size, education level, fertilizers, irrigation system, farming experience, volume of water, extension service, off farm income, gender, and cooperative membership have positively influenced productivity. Factors namely family size, education level, fertilizers, irrigation system, farming experience are statistically significant at 1% level to influence productivity while volume of water, extension service, off farm income were positively influenced at 5% level. Hence gender, cooperative membership was positively influenced at 10% level. Five factors such as labour source, age, price of produce, distance to market, agricultural credit, negatively influenced productivity in study area. One factor namely land size/plot did not influenced productivity.

The results show that among the variables, factors namely family size, education level, fertilizers, irrigation system, farming experience have high positive significant influence on productivity (p values <0.01) while the as labour source, age, price of produce, distance to market, agricultural credit have high negative significant influence on the productivity under irrigation water (p <0.01). It is expected that a unit increase in family size would contribute 1.3-unit increment in the productivity in study area under irrigation system, while holding other factors constant. A 1% increase in extension should increase productivity by 1.4%. This is because more contact with these organizations technicians enhances sharing of information regarding the technology and accessibility of water for irrigation. In the other word service contact is enhanced by

attendance to group meetings from where the farmers are met by extension agents. Farmers who fail to participate in such meetings/trainings often get little information and thus lower usage of agricultural inputs properly.

A 1-year increase in farming experience should increase productivity by 0.32%. This is because the longer being in farming, the better to know different agricultural practices hence, high reduction of challenges example irrigation system and pests and diseases control. Factors such as age, price of produce, distance to market, agricultural credit, negatively influenced productivity. This implies that 1-kilometer increase to the market should reduce productivity by 1.2%. This shows that accessibility to market is a key factor in the level of irrigation system use and agricultural productivity. For a unit increase in reduction of price of produce, there is a 0.3% increase in the reduction of agricultural productivity in study area under, holding other factors constant.

Economic (Cost-Benefit) of Using Irrigation System at Kagitumba, Nasho and Muyanza Schemes

The economic analysis of profitability of maize farming associated with this three-irrigation system (water pump, drip, and sprinkler) at three sites such as Kgitumba, Nasho, and Muyanza of the participating farming households were analysed and compared using the economical method of conventional cost benefit. Economically, the measures of farmers' economic conditions encompass the adoption cost, operational cost, productivity, profitability, and farm efficiency.

Table 1. Demographic and Socioeconomics of the Respondent's Farmers.

	Kagitumba		Nasho		Muyanza		Total	
	F	%	F	%	F		F	%
Gender								
Male	44	55	41	51.25	37	46.25	122	50.8
Female	36	45	39	48.75	43	53.75	118	49.2
Age								
Less than 30	16	20	20	25	9	11.25	45	18.8
31-45	24	30	33	41.25	24	30	81	33.8
46-60	33	41.25	17	21.25	35	43.75	85	35.4
61and above	7	8.75	10	12.5	12	15	29	12
Marital Status								
Single	16	20	21	26.25	16	20	53	22.1
Married	37	46.25	34	42.5	40	50	111	46.3
Divorced	18	22.5	15	18.75	11	13.75	44	18.3
Widower	9	11.25	10	12.5	13	16.25	32	13.3
Education level								
None	31	38.75	22	27.5	25	31.25	78	32.5
Primary	20	25	27	33.75	18	22.5	65	27.1
Secondary school	15	18.75	10	12.5	16	20	41	17.1
Vocation	10	12.5	18	22.5	14	17.5	42	17.5
University	4	5	3	3.75	7	8.75	14	5.8
Farming Experience								
Less than 5	11	13.75	17	21.25	6	7.5	34	14.2
6-10	23	28.75	21	26.25	26	32.5	70	29.2
11-15	22	27.5	20	25	30	37.5	72	30
16-20	17	21.25	13	16.25	10	12.5	40	16.6
Above 21	7	8.75	9	11.25	8	10	24	10
Land Size (ha)								
Less than 1	17	21.25	12	15	75	93.75	104	43.3
1.1-2	25	31.25	23	28.75	4	5	52	21.7
2.1-3	16	20	17	21.25	1	1.25	34	14.2
3.1-4	12	15	15	18.75	0	0	27	11.2
Above 4.1	10	12.5	13	16.25	0	0	23	9.6

Table 2. The Probit Regression Analysis of the Factors Influencing Farmers to Use Irrigation system.

Factors	Water pump irrigation system		Drip irrigation system		Sprinkler irrigation system	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Gender	0.649	0.319	0.324	0.159	0.973	0.478
Age	-0.447	0.305	-0.073	0.152	0.207	0.002
Education level	1.295	0.211	-0.647	0.105	1.942	0.316
Farming experience	0.008	0.000	-0.089	0.005	0.267	0.002
Land Size	0.621	0.176	0.310	0.088	-0.535	0.264
Family income	0.001	0.000	-0.007	0.116	0.000	0.000
Labor	-0.191	0.077	0.095	0.038	0.286	0.115
Location	2.774	0.267	-0.387	0.133	4.042	0.400
Proximity to water	-1.056	0.090	0.499	0.045	1.498	0.135
WUA membership	0.749	0.361	2.374	0.185	1.123	0.542
Constant	3.37	5.24 1	0.407	0.286	0.785	0.551
Log likelihood	-34.755		-41.548		33.634	
LR (likelihood ratio) test Chi2	145.43		239.13		207.57	
Prob > Chi2	0.0000		0.0000		0.0000	
Pseudo R-squared	0.7768		0.7920		0.8587	

Table 3. The Factors Influencing Productivity of Irrigation System Use in Study Areas.

Variables	Coefficient	Standard Errors	P-value
Land size/plot	0.649	0.319	0.684
Labour source	-0.447	0.305	0.057
Family size	1.295	0.211	0.000
Gender	0.178	0.055	0.086
Age	-0.621	0.176	0.073
Education level	0.162	0.232	0.005
Fertilizers	0.191	0.077	0.001
Irrigation system	0.774	0.267	0.000
Volume of water	0.999	0.09	0.013
Off farm income	0.749	0.361	0.052
Price of produce	-0.298	0.583	0.000
Distance to Market	-0.138	0.137	0.077
Agricultural credit	-0.697	0.213	0.000
Farming experience	0.319	0.304	0.000
Extension Service	1.421	0.113	0.035
Cooperative membership	0.224	0.306	0.081
Constant	0,774	1,402	0.000
Number of obs = 240, R-squared = 0.8307			
F(16, 223) = 44.22, Adj R-squared = 0.8365			

Table 4. Economic (Cost-Benefit) Analysis of Using Irrigation System at Kagitumba, Nasho and Muyanza Schemes.

Object	Kagitumba	Nasho	Muyanza	Overall Average	F-Test (Sig)
Farm revenue	970 140.5	1 025 100	629 080	874 773.5	0.001
Total variable cost	356500.5	385300	326450	356083.5	0.000
Fixed cost (Depreciation)	64451.7	86559	58500	69836.9	0.000
Total cost = (2) + (3)	420952.2	471859	384950	425920.4	0.003
Yield (kg/ha)	4850.7	5125.5	3145.4	4373.867	0.000
Gross margin = (1) -(2)	613 640	639 800	302 630	518 690	0.000
Net farm income (crop value per ha) = (1) - (4)	549 188.3	553 241	244 130	448 853.1	0.000
Operating expense ratio = (2)/(1)* 100	36.7	37.6	51.9	42.1	

Depreciation expense ratio = (3)/(1)*100	6.64	8.4	9.3	8.1
Net farm income ratio = (7)/(1)*100	56.6	53.9	38.8	49.8
Benefit-to-cost ratio = (1)/(4)	2.3	2.2	1.6	2

The findings in table 4 by comparison indicated the investment costs and economic returns per unit area of maize farming (ha) of the participating maize farmers under the three irrigation schemes (Kgitumba, Nasho, and Muyanza). By comparison, the Net farm income per ha at Nasho schme site was largest with (553 241 Rwf), followed by the (549 188.3 Rwf) at Kagitumba scheme site and (244 130 Rwf) at Muyanza scheme site farmers. This indicates that the greatest maize yields per unit area of cultivation occurred under the sprinkler irrigation system particularly at Nasho and Kagitumba where these two types of irrigation are modern developed. Meanwhile, water pump farmers main concentrated at Muyanza scheme incurred the smallest total cost per ha of (384950 Rwf) which is less than the average cost of the three schemes (425920.4 Rwf). This should due to some good agricultural practices that are not taken into consideration which in turn cause a high reduction of productivity of maize per unit area. In addition, the low economic return at Muyanza scheme was largely attributable to the fuel costs to operate the pumps and labour paid daily for this pump. The findings also pointed out that the farm revenue, total cost, and net farm income were statistically different among the three-irrigation system at these three schemes ($p < 0.01$).

The research findings indicated that the lowest operating expense ratio which is a measure of what percentage of farm revenue is allocated to the variable operating expenditures was achieved at Kagitumba irrigation scheme (36.7%), followed by (37.6%) at Nasho irrigation scheme and (51.9%) at Muyanza irrigation scheme. In addition, the depreciation expense ratio was highest at Muyanza irrigation scheme (9.3%), followed by (8.4%) and (6.6%) at Nasho and Kagitumba schemes respectively. Further, the economic investigation and analysis revealed that despite some negative effect like the high depreciation cost and environmental pollution, the utilization of the water pump irrigation system was common in the study area due to its ease of deployment to the proximity of water sources, and easy support (subsidies) from government where a committed farmer pay 50% of the total cast of this pump and other 50% are paid by government.

As the highest net farm income ratio of (56.6%) was found at Kagitumba irrigation scheme compared to those of (53.9%) found at Nasho and (38.8%) found at Muyanza irrigation scheme. Similarly, the benefit cost ratio was the highest (2.3), suggesting that one-dollar of investment at Kagitumba irrigation scheme generates 2.3 dollars of revenue. The Nasho (2.2) and Muyanza (1.6) irrigation scheme followed this.

However, in order to improve and increase efficiency in terms of technique and crop yield, farmers should be encouraged to grow maize and irrigate as well as possible according to the crop water requirement. Likewise, government should increase the extension service that help agronomist to better provide knowledge and shills pertaining to the factors of production, especially the proper application of fertilizers and pesticides, improved seeds which in turn affect significantly maize production and productivity both in quality and quantity. Farmers should be followed and trained on GAP particularity at Muyanza scheme where yield per ha still too low compared to the other two sites and desired production per unit area. A proper application of GAP directly rise maize with an increase rate and decrease cost of production with a decreasing rate.

Factors Influencing Farmers' Willingness to Pay for Irrigation Water

The results of the regression are presented in Table 5. The results indicate that 76.42% of the variation in the dependent variable is explained by the explanatory variables. The overall significance and fitness of the model is indicated by the F-value, which in this case is 57.65 and is significant at 1% level, indicating that the explanatory variables reliably statistically predict the dependent variable.

Table 5. Factors Influencing Farmers' Willingness to Pay for Irrigation Water.

Variables	Coefficient	Standard Errors	P value
Age	-0.076	0.024	0.014
Gender	0.036	0.044	0.414
Household size	-0.013	0.009	0.066
Education level	0.056	0.037	0.009
Off farm income	0.119	0.082	0.002
Access to credit	0.074	0.043	0.000
Land size	-0.694	0.206	0.071
Rate of rain fall	-0.967	0.296	0.000
Money gained from harvest	0.391	0.676	0.067
Money payed per season	0.035	0.028	1.923
Inputs cost	-0.766	0.322	0.921
Constant	1.802	0.508	0.000

Number of observation = 240, Prob>F= 0.0000
$F(11,228) = 57.65$, $R2 = 0.7642$

Out of the eleven explanatory variables, four such as education level, off farm income, credit was statistically and significant at 1% level to influence the farmers' willingness to pay for irrigation water in study area. This implies that 1% increase in credit access the farmers' willingness to pay for irrigation water should be increased by 0.074%. The results also indicated that the

off-farm income was statistically and significant to influence farmers' willingness to pay for irrigation water at 1% level. This explains that households that earned off-farm income should willing to pay more compared to that not earning off-farm income.

Access to credit also positively and significantly influenced farmers' willingness to pay for irrigation water. This could be due to the possibility that part of the access to credit offered is used to pay for irrigation water, among other inputs increasing of agricultural production and productivity. Education level on best management of irrigation water and application system positively influenced farmers' willingness to pay for irrigation water. Farmers with high education level understand more agricultural best practices and better management of irrigation water system and use. This class of educated farmers were found to be more willing to pay more compared to those of low class who are not willing to pay for irrigation water.

Five factors such as age, household size, land size, rate of rain fall, and inputs cost were found to have a negative relationship with farmers' willingness to pay for irrigation water. For example, rate of rainfall was found to be negative and statistically and significant at 1% level to influence farmers' willingness to pay for irrigation water. This implies that 1% increase in rate of rainfall should reduce the farmers' willingness to pay for irrigation water by 0.97%. While a 1%, increase in household size should reduce the farmers' willingness to pay for irrigation water by 0.013%.

CONCLUSION

The current research investigated the impact of small-scale irrigation system use in agriculture farming in Rwanda. A case study of Kagitumba, Nasho and Muyanza schemes.

The findings of this research indicated that (50.8%) of the respondent farmers (240 farmers) were male and 41.9% were female. The respondents' ages were classified into four age groups. The findings showed that younger generations are currently abandoning agriculture farming due to the lack of initial capital and other support to enter the sector properly which in turn cause a huge lack of labour force and high urban migration. The respondents' years of maize farming experience were classified into five lengths of time and the findings of this study indicated that the overall, the 11–15 group had the largest number of respondents (30%). The land sizes were categorized into five classes as shown in table above. The findings revealed that the majority of farmers have farm less than 1ha represented by (43.3%). The results indicated farmers with small land are concentrated in Muyanza site in Rulindo district with less than 1 ha. While big farmers with big farm are highly located in Nasho, and Kagitumba sites in Kirehe and Nyagatare districts respectively where a farm should have even more than 5ha.

The water pump and drip irrigation system and age had a significant negative correlation with each other (β = -0, 0735, $p < 0.05$), while this association was significantly positive between the sprinkler use and age ($\beta = 0.207$, $p < 0.05$). Land size was significantly positively associated with the water pump use ($\beta = 0.621$, $p < 0.01$). The water pump and sprinkler irrigation system use and farm income were significantly positively correlated ($\beta = 0.000$, $p < 0.01$), which suggested that the increased income from the sales of maize contributed to the greater likelihood of the two-system utilization. The water users' associations membership and the water pumper, drip and sprinkler irrigation systems were significantly positively correlated ($\beta = 2.3745$, $p < 0.01$).

The findings of this research revealed that factors namely family size, education level, fertilizers, irrigation system, farming experience are statistically significant at 1% level to influence productivity of maize crops at these irrigation schemes. The results indicated that by comparison, the Net farm income per ha at Nasho schme site was largest with (553 241 Rwf), followed by the (549 188.3 Rwf) at Kagitumba scheme site and (244 130 Rwf) at Muyanza scheme site farmers. The research findings showed that the lowest operating expense ratio which is a measure of what percentage of farm revenue is allocated to the variable operating expenditures was achieved at Kagitumba irrigation scheme (36.7%), followed by (37.6%) at Nasho irrigation scheme and (51.9%) at Muyanza irrigation scheme. In addition, the depreciation expense ratio was highest at Muyanza irrigation scheme (9.3%), followed by (8.4%) and (6, 6%) at Nasho and Kagitumba schemes respectively. The highest net farm income ratio of (56, 6%) was found at Kagitumba irrigation scheme compared to those of (53.9%) found at Nasho and (38.8%) found at Muyanza irrigation scheme.

Similarly, the benefit cost ratio was the highest (2.3), suggesting that one-dollar of investment at Kagitumba irrigation scheme generates 2.3 dollars of revenue. The Nasho (2.2) and Muyanza (1.6) irrigation scheme followed this. Out of the eleven explanatory variables, four such as education level, off farm income, credit was statistically and significant at 1% level to influence the farmers' willingness to pay for irrigation water in study areas.

RECOMMENDATIONS

After the findings and conclusion provided above, the following recommendations were specified:

The results indicated that by comparison, the Net Farm Income per ha at Muyanza scheme site was too low compared to the desired yield per unit area and compared to those found at Kagitumba and Nasho irrigation schemes. Therefore, farmers should be encouraged to better use irrigation system, improved seeds, apply fertilizer and pesticides on time and apply all advised quantity of those inputs.

As the depreciation of fixed infrastructures is one of the most measures to main them, farmers should be encouraged to be registered in water user's associations

and sensitized on having sprit of willingness to pay for irrigation water which in turn support/or help in to replace the destroyed and or old materials facilitating irrigation system on site.

The low productivity should be influenced by several factors like lack of water conservation, shallow knowledge about water management by the farmers, agricultural mechanization nearly absent and less operational, marshlands badly and less exploited. However, government should increase investment in marshlands management, water conservation, integration of erosion control and soil management in the technological package to extend to the farmer as well as to facilitate irrigation system in agriculture farming in long run.

The government should expand the drip and sprinkler irrigation system in the another agro climatic zones in order to reduce the dependence of farmers on rain fed agriculture which main disturbed by climate change especially in eastern province where actually rain is lower than other provinces of Rwanda (e.g. Western and Northern).

Drip and sprinkler irrigation systems are very cost and expensive infrastructures for installation and maintenance. Therefore, a high attention should be made by farmers and technicians during agricultural practices in order to sustain and maintain them in long run.

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Research Article

Period of effective catching of insect pests and natural enemies in light traps

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ABSTRACT
Light trap helps to protect natural enemies and manage destructive insect pests in rice farming ecosystem. Light trapping time at night is not identified, for organic farming in farmers level its essential to identified proper timing at night. The experimental light trap was set up at Sagordi rice farm, Bangladesh Rice Research Institute, Barishal, during T. Aman rice season in 2019-2020. The time of catching insects by light trap were divided in six different times in a night and defined as treatments (T_1= 17.20 to 18.20, T_2= 18.20 to 19.20, T_3= 19.20 to 20.20, T_4 =20.20 to 21.20, T_5=21.20 to 22.20, T_6= 22.20 to rest of night insects caught at light trap) in this study. Each treatment has had four replications. Yellow sticky trap used to catch and trapped insect and natural enemyRice insect pests and their natural enemies were counted and recorded manually. The caught of yellow stem borer increased and green leafhopper were decreased from treatment, T_1 to treatment, T_6. During dusk to first four hours, the percentage of caught was approximately 69.28% insect pests. Overall, the percentages of insect pests trapping were 89.65% and natural enemies were 10.35% during the experimental period. The ratio of destructive insect pests caught was highest compared to that of natural enemies in light trap of rice ecosystem.
Keywords: Light trap, management, insects, monitoring, Rice (*Oryza sativa* L.).

INTRODUCTION

Rice, *Oryza sativa* L., is an essential staple food for half of the world's population. In 2012, rice was grown on over 158 million hectares and produced 465 million tons globally, with Bangladesh alone producing 34 million tons of milled rice (Akhtar et al., 2010; Hu et al., 2014; IRRI, 2014; Ali et al., 2021). In Bangladesh, rice is the primary food crop and occupies 75% of cultivated land, providing crucial calories and protein for the average daily diet of adults (Ganesh-Kumar et al., 2012). Rice is also a major source of income, supporting nearly 15 million farm households, predominantly small and marginal farmers (Bhuiyan et al., 2004; Bangladesh Bureau of Statistics, 2008).

However, the increasing global population requires an increase in rice production, yet this is hindered by various obstacles, including biotic stressors such as insect pests (Hossain et al., 2007; Ali et al., 2020; Kennedy, 2002; Miao et al., 2011). Insect pests can have a significant impact on rice cultivation in Bangladesh. These pests can cause significant yield losses (Islam et al., 2003; Datta et al., 2021), which can negatively impact the livelihoods of farmers and the overall food security of the country. It has been recorded that a total of 266 different types of herbivores have been found in rice ecosystems, with 232 of them being arthropod species found in Bangladesh. These herbivores cause significant yield losses in the country (BRRI, 2016). However, when considering only the major insect pests that cause significant yield losses in large numbers, the number narrows down to only 15-20 species (Islam et al., 2003). Insect pests such as green leafhopper, zigzag leafhopper, brown planthopper, and white-backed planthopper are known to cause significant damage to rice crops. These pests can suck the sap from the plant, weakening it and reducing its ability to produce grain. Additionally, these pests can act as vectors, spreading pathogens that further damage the crop. Insect pests can also impact the quality of the grain produced. For example, the brown planthopper can cause grain to become discolored and shrunken, making it less desirable for consumption or sale. This not only results in financial losses for farmers, but it also affects the overall food security of the country as less grain is available for consumption.

Currently, the control of insect pests in rice cultivation in Bangladesh relies heavily on the use of chemical pesticides. During the years 2011 and 2012, around 20-24 thousand tons of formulated insecticide were used in Bangladesh, with more than half of that amount being applied to control rice insect pests (BCPA, 2013). However, this approach can have negative impacts on both human health and the environment. Additionally, the overuse of pesticides can lead to the development of pesticide resistance in insect populations, making pest control increasingly difficult. Effective pest management strategies are needed to address this issue, including the use of non-toxic pest control methods, integrated pest management, and research on new pest control technologies.

Light traps have been widely used in agriculture, forestry, and other industries to control insect pests. They are considered to be an efficient and cost-effective method for monitoring and reducing pest populations and can provide valuable data for research and pest management programs. (Young, 2005). Light traps can be used to attract a wide range of insects, including moths, beetles, and other nocturnal insects (Leinonen et al., 1998; Fayle et al., 2007). The efficiency of light traps can be affected by various factors such as the type of trap, the time of day and night, the season, and the duration of sampling (Thomas & Thomas, 1994; Axmacher & Fiedler, 2004; Summerville & Crist 2005; Beck & Chey, 2007). Light traps are commonly used in rice farming in Bangladesh to control pests, as they are considered to be the most efficient method for monitoring nocturnal insects, particularly moths, by providing population and comparable data. They can be set up as permanent installations or used as portable devices, depending on the specific application.

Visual lures, such as bright colors and shapes, are used to attract pests in light trapping. The efficiency of trapping harmful insects depends on factors like the amount of moonlight, the percentage of polarized light, and the phase of the moon. Studies have shown that the highest number of species can be collected during the new moon or close to the first and last quarter (Nowinszky and Puskas, 2012). This research has been effective in identifying the optimal lighting period for trapping insects and comparing the catch of rice pests and natural enemies.

MATERIALS AND METHODS

Setting light trap: Arthropods that are attracted to light, such as insect pests and predators, were collected from a light trap device known as the Pennsylvania type (Fig. 1) at the rice farm of the Bangladesh Rice Research Institute (BRRI) Regional station in Barishal (22°67'29″N, 90°35'49″E). This trap is a permanent set-up at the farm.

Treatments: The treatments were as follows, (T_1= 17.20 to 18.20, T_2= 18.20 to 19.20, T_3= 19.20 to 20.20, T_4 =20.20 to 21.20, T_5=21.20 to 22.20, T_6= 22.20 pm to rest of night caught at light trap.

Data collection: Data were collected from 17 to 20 November 2020 at Sagardi rice farm, BRRI, Barishal in T. Aman 2019 - 2020. Yellow sticky trap was used to catch and trapped insect and natural enemies. The four replications yellow sticky trap were used. Rice insect pests and their natural enemies counted and recorded manually.

Statistical analysis: The results are displayed in the form of average values obtained from multiple samples (replications), accompanied by error bars showing the standard deviation (SD). Significance was evaluated using a one-way ANOVA test in combination with Tukey's multiple comparison analysis.

Fig. 1. Pennsylvania type light trap at BRRI, R/S, Barishal during experiment period

RESULTS AND DISCUSSION

Light trap is an important tool for monitoring rice insect pest and natural enemy at farming ecosystem. Light attracts both the harmful insect pests and predatory natural enemies. Light trap caught green leafhopper (GLH), white leafhopper (WLH), orange leafhopper (OLH), zigzag leafhopper (ZLH), brown planthopper (BPH), white backed planthopper (WBPH), yellow stem borer (YSB), leaf folder (LF), caseworm (CW), long horn grasshopper (LHG), Long horn cricket (LHC) and rice bug (RB) insect pest. Another side same device was also caught beneficial carabid beetle (CDB), ladybird beetle (LBB), staphylinid beetle (STPD), spider (SPD), green mirid bug (GMB), dragon fly (D. fly), ear wig (EW) and parasitoids natural enemies. Highest number of insect pest caught at second day first trapping hour (T_1), second highest insect pest trapping found first day then third and fourth day at same treatment (T_1) in Pennsylvania light trap (Fig. 2). Young (2005) also reported moths were caught in light trap and demonstrated the insects with comparing data. In case of natural enemies, higher caught follows fourth, first and second consecutive days (Fig. 2). Second treatment (T_2) found higher insect caught in second day that follows

first, third and fourth consecutive days (Fig. 2). Beneficial natural enemy caught found higher to lower rate at first to fourth days continuously (Fig. 2). Third treatment follows first to fourth day's insect and natural enemy caught decreasing pattern exceptional second days of natural enemy (Fig. 2). Fourth and fifth treatment follows first to third days insect and natural enemy caught at decreasing pattern without fourth day (Fig. 2). Last treatment (T_6) follows decreasing pattern of insect caught but in case of natural enemy follows first, fourth, second and third consecutive days caught (Fig. 2). From the data it is crystal clear that all the treatments are capable to catch insect pests in different time periods. The result is similar to previously reported data of Fayle et al. (2007). During whole experimental period highest insect pest (1663) caught 18 November and lowest (200) caught 20 November 2019. Same experiment natural enemy caught highest (341) in 19 November and lowest (35) in 18 November, 2019.

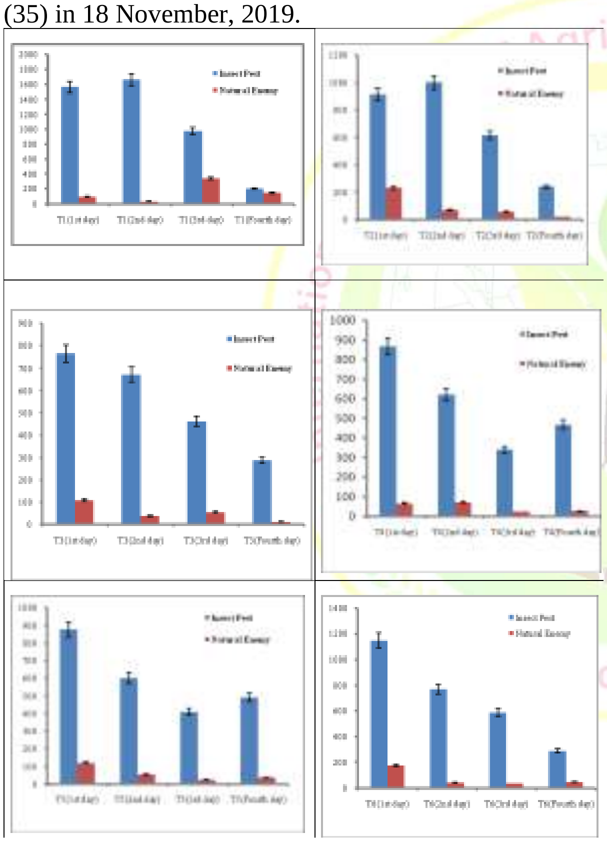

Figure 2. Treatment wise caught of insect pests and natural enemies in light trap

Yellow stem borer, another destructive pest was also found in light trap. With the increasing period, treatment T_1 to T_6, yellow stem borer caught also increased, for example a number of 24, 41, 109, 124, 135, 188 yellow stem borers caught at T_1, T_2, T_3, T_4, T_5, T_6 treatment, respectively. Green leafhopper, vector of rice tungro virus, caught was in decreasing with the treatment. There might be several reasons for the low number of trapped insects. Dusk to midnight, the ratio of yellow stem borer and green leafhopper caught was vice versa. Insect pest and natural enemy has relationship with trapping hour in light trap. Different insect pest and natural enemy follows to highest caught in different pattern of trapping hours in light trap. Borer and hopper have strong inverse relationship to attract and trapped in light trap.

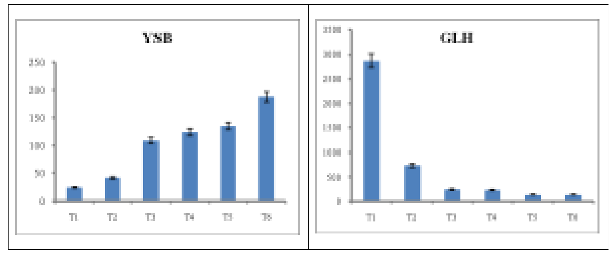

Fig.3. Yellow stem borer and green leafhopper caught pattern at different treatment in light trap

Table 1. Percentage of insect pest and natural enemies' population of different treatment in light trap

Population	T1	T2	T3	T4	T5	T6
Insect (%)	26.14	16.47	12.99	13.66	14.12	16.60
Natural Enemy (%)	32.03	19.62	11.02	9.73	12.05	15.55

Out of all the treatments, T1, which refers to the twilight (godhuli) traps, caught the highest number of insect pests (26.14%) and natural enemies (32.03%) (Table 1). This treatment trapped destructive pests such as the green leafhopper, zigzag leafhopper, brown planthopper, and white-backed planthopper, as well as beneficial pests such as the carabid beetle, green mirid bug, staphylinid beetle, and parasitoids. From dusk to the first four hours, 69.28% of insect pests were caught. The number of insect pests caught decreased during the first three hours (17.20 to 20.20) and the number of beneficial natural enemies caught also decreased during the first four hours (17.20 to 21.20). Therefore, trapping light during the twilight to the first three or four hours is important for catching the maximum number of insect pests.

Table 2. Comparative caught of insect and natural enemy population in light trap

Population	Insect	Natural enemy
Total Caught	16825	1942
Percentage (%)	89.65	10.35

Generally, more than 8.5 times insect pest caught than natural enemies in light trap during experiment. Its good sign for protect and preserve our natural enemy biodiversity within rice ecosystem. During study period highest 16825 no. insect pest and 1924 no. of natural enemy caught and trapped. Higher percentage of insect pest population (89.65%) caught compared to natural enemies (10.34%) in light trap. Light trap is comparatively safer in case of protect beneficial natural enemy in rice field at farmers' level.

CONCLUSION

This study found that yellow stem borer and green leafhopper insect caught inverse relationship at increasing night period. Among all the treatments, first one (T_1=17.20 to 18.20) caught highest insect pest and natural enemy. Dusk to first four hours treatment (T_1 to T_4) caught maximum 69.28% insect pests. Overall insect pest trapping and caught 89.65% and natural enemy 10.35% during experimental period. Every treatment was hours interval period from twilight to dawn, but last treatment T_6 (22.20 to down) time period was so high. Future recommendation is to split dusk to down every single hour's interval treatment. Biotic and abiotic factors should also be considered for relationship with insect pests and natural enemy caught.

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Research Article

OPEN ACCESS

Accessing the efficacy of different doses of phosphorus on growth and yield of spring maize (*Zea mays* L.) at Gulmi, Nepal

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ABSTRACT
Phosphorus is one of the most important crop-limiting elements which plays a crucial role in the growth as well as the development of the plant. To meet the crop need and to obtain the efficiency of fertilizer they should be applied in appropriate doses. Thus, an experiment including six different doses of phosphorus as a treatment (0, 20, 40, 60, 80, and 100) kgha^{-1} was designed to identify the optimum dose of phosphorus for better growth and yield of spring maize. The study was carried out according to one factorial RCBD with four replications of six treatments at Satyawati rural municipality, Khaireni, Gulmi from February-June 2022. Maize seeds (Arun-2) treated with Bavistin were sown by maintaining a spacing of 75*25 cm^2. Different observations like biometrical, phenological as well as yield-attributing characters were recorded. The results showed that the different doses of phosphorus significantly affected the recorded parameters. The plant height was found highest (164.92cm) with 100kg P_2O_5 ha^{-1} which was statistically similar to the plant height (155.57cm) obtained at 80kg P_2O_5 ha^{-1}. The longest days to silking and tasseling were found at 0 kg P_2O_5 ha^{-1}. Likewise, cob length (23.05cm), number of grains per kernel (26.76), and shelling percentage (74.48%) were highest in plants with 100kg P_2O_5 ha^{-1}and number of kernel row per cob (15.19), number of grains per cob (406.22) [1] and grain yield (6203.29kg ha^{-1}) was highest in plants with 80 kg P_2O_5 ha^{-1}. The maximum harvest index percentage (38.13%) was obtained in 60 kg P_2O_5 ha^{-1}. There was no significant variation of treatment on thousand-grain weight. This research showed that the treatment of 80kg P_2O_5 ha^{-1} was found to boost the yield of maize by enhancing the growth and yield attributes of maize. Thus, for a better and improved yield of maize 80 kg P_2O_5 h^{-1} is recommended in Gulmi.
Keywords: Arun-2, Fertilizer dose, Yield parameters, Nutrients.

INTRODUCTION

In the global scenario, maize is the most important crop after rice. It is believed to be domesticated by the native people of Mexico about 9000 years ago (Matsuoka, et al., 2002) which has many domestic and industrial uses. Globally, its production area is about 197 million hectares and production is about 1,137 million tons (Erenstein, Jaleta, Sonder, Mottaleb, & Prasanna, 2022). United States of America, China, Brazil, Argentina, Ukraine, and India are the top countries for maize production with a production of 392,450,840 tons, 257,348,659 tons, 82,288,298 tons, 43,462,323 tons, 35,801,050 tons and 27,820,000 tons respectively.

In many developing countries, maize is considered a primary staple crop. In Nepal, maize is 2nd most essential crop in cultivated areas, with production and productivity contributing 9.5% to AGDP and 3.5% to GDP (KC, Karki, Shrestha, & Achhami, 2015) which is mainly grown for food, feed, and fodder as well as for industrial raw materials. The total maize production area is 9,79,776 ha with a production of 29,97,733 metric tons (MoALD, 2021). Among crop plants, maize has the highest production potential and has the most variation in its morphology. At present, the lower yield of maize in Nepal than that of other Asian countries may be probably due to a lack of quality seeds and proper use of inputs. The most important input in increasing agricultural productivity is Chemical fertilizer, according to Nepal's agriculture perspective plan and agriculture development strategy (Panta, 2019). Since, genotype, environment, and crop management influence

yield, for better production fertilizer management is very crucial. Nitrogen is the foremost crucial fertilizer for maize production and after that, phosphorus is the most crop-limiting element in the majority of soil (Wojnowska, Panak, & Seikiewiez, 1995). Mainly in the hilly regions of Nepal, the majority of the soils lack soil-available phosphorus so, phosphorus could be a restrictive factor for Maize production (Shrestha, Amgain, & Aryal, 2016). Phosphorus plays a very important role in root growth and development as well as plant reproduction. Maize plants lacking phosphorus will results in stunted growth and limited development of the root system (Masood, et al., 2011) and also produce smaller ears with fewer kernels than normal (Sapkota, Shrestha, & Chalise, 2017). Another study by Baral, Adhikari, & Shrestha (2016) found the increased dose of phosphorus significantly reduces the days to 50% tasselling and silking. Besides this phosphorus application also increases the soil available P and K. Adequate phosphorus application results in quick quality vegetative growth and earlier maturity with quality grain. So, phosphorus application in an appropriate dose is crucial for better growth and yield of maize. Thus, the goal of the current study was to find the appropriate dose of phosphorus for better growth and yield of spring maize.

MATERIALS AND METHODS

Study area

This study was conducted to know how the growth and yield of spring maize were affected due to different doses of phosphorus at Satyawati rural municipality-6, Khaireni, Gulmi, from February to June 2022 located at Latitude: 28° 0' 55" north and Longitude: 83° 26' 21" east (Mapcarta, 2022).

Weather data

During the experiment period, average monthly weather data were recorded from February to June 2022. The average maximum and average minimum temperature for the cropping duration were 25.17˚C and 14.66˚C respectively. The maximum relative humidity for the cropping period was 52% and the minimum was 10.8% (Nasa Power, 2022).

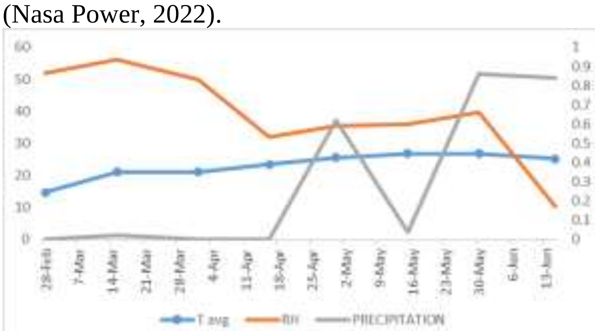

Figure 1: Weather data of experimental location, 2022, at Satyawoti-6, Khaireni, Gulmi

Variety details

Arun 2 variety of maize was used for the research. It is dwarf spring maize which was recommended in the Terai, Inner Terai, and lower hills that grows up to a height of 140cm to 200cm tall.

Experiment details

The experiment was carried out according to one factorial Randomized Complete Block Design (RCBD) including four replications of six treatments with each plot size 3 m *2.5 m (7.5 m^2) by maintaining the spacing of 75 cm*25 cm between the rows and plants respectively. For the routine test of soil, analysis of soil was done before conducting the research by taking samples randomly from each replication. Soil samples were collected from 0-15cm depth using the shovel and were dried, and made fine. A soil kit box was used for the analysis. The soil was sandy loam in texture which was identified by using the textural triangle method. PH was 6.7 which is best suited for maize. Nitrogen and Soil available phosphorus was medium meanwhile available potassium was low.

The field was ploughed with a mini tiller 15 days before seed sowing to bring the soil under good tilth. In all experimental plots, the FYM @5 kg per plot area (7.5 m^2) was applied and mixed uniformly into the soil during the first land preparation. The amount of phosphatic fertilizer that is required for each treatment was calculated separately. As a basal dose, P_2O_5 @ 0 g, 33 g, 65.2 g, 98 g, 132 g, and 165 g per plot for treatments of 0, 20, 40, 60, 80, and 100 kg p ha^{-1}, respectively, full dose of recommended potassic fertilizer and half dose of nitrogen fertilizer were applied in all plots. Arun-2 Seeds treated with Bavistin were sowed with the help of Jab-planter after final land preparation. Sowing was done on 2nd March 2022. Later, at the knee-high stage and the tasselling stage, the remaining half of the nitrogen dose was applied in two equal portions. The first manual weeding and earthing up were done 40 days after sowing (DAS). After that second manual weeding was performed at 60 DAS. Harvesting was done on June 15, 2022, manually.

Observation recorded

A biometrical observation like plant height, and number of leaves; Phenological observation like days to 50% tasseling, days to 50% silking, yield attributing characteristics like shelling %, thousand-grain weight, cob length, number of kernel row per cob, number of kernels per row, number of kernels per cob, thousand-grain weight and grain yield were calculated. The formula used for calculating grain yield (kg ha^{-1}) has given below:

$$\text{Yield} = \frac{10000}{A * B} \times \frac{C \times R \times K \times TGW}{1000 \times 1000}$$

Where,
A = Row-to-Row spacing (m)
B = Plant-to-Plant spacing (m)
C = Number of cobs per plant
R = Number of rows per cob
K = Number of kernels per kernel row
TGW= Thousand grain weight (gm)

RESULTS AND DISCUSSION

Plant height

Table no. 1 shows the effect of different doses of phosphorus on plant height on different days after sowing. Plant height was found to be increased with increasing the dose of P_2O_5 from 0 kg ha^{-1} to 100 kg ha^{-1}. At 30DAS, maximum plant height (38.07cm) was obtained at 100 kg P_2O_5 ha^{-1} followed by plant height (36.57cm) and (34.5cm) obtained at 80 kg P_2O_5 ha^{-1} and 60kg P_2O_5 ha^{-1} respectively. Minimum plant height (28.14cm) was obtained at 0 kg P_2O_5 ha^{-1}.

At 45 DAS, the maximum plant height (105.86cm) obtained with 100kg P_2O_5 ha^{-1} was statistically similar to the plant height (101.02cm) obtained with 80 kg P_2O_5 ha^{-1} and the minimum plant height (72.04cm) obtained at 0 kg P_2O_5 ha^{-1}. At 60 DAS maximum plant height (158.64cm) was obtained with 100kg P_2O_5 ha^{-1} and minimum plant height (113.04cm) was obtained at 0kg P_2O_5 ha^{-1}. Finally at 75 DAS, similarly maximum plant height (164.93cm) was obtained at 100kg P_2O_5 ha^{-1} and minimum plant height (129.86cm) was obtained at 0kg P_2O_5 ha^{-1}. High phosphorus doses improve the root system and nutrient absorption which ultimately enhances plant growth. Phosphorus fertilization is used for a variety of physiological and metabolic processes, enhancing vegetative growth (Pal, et al., 2017).

Table 1. Effect of different doses of phosphorus on plant height of spring maize (Arun-2) at Khaireni, Gulmi, 2022

Treatment	Plant height(cm)			
	30 DAS	45 DAS	60 DAS	75 DAS
0 kg P_2O_5 ha^{-1}	28.14^{d}	72.04^{c}	113.04^{d}	129.86^{c}
20 kg P_2O_5 ha^{-1}	32.43^{c}	81.46^{bc}	120.50^{cd}	143.82^{bc}
40 kg P_2O_5 ha^{-1}	32.39^{c}	80.11^{bc}	127.50^{cd}	137.76^{bc}
60 kg P_2O_5 ha^{-1}	34.50^{bc}	87.11^{b}	138.57^{bc}	147.38^{abc}
80 kg P_2O_5 ha^{-1}	36.57^{ab}	101.02^{a}	154.82^{ab}	155.57^{ab}
100 kg P_2O_5 ha^{-1}	38.07^{a}	105.86^{a}	158.64^{a}	164.93^{a}
LSD(0.05)	3.47	13.59	19.40	18.49
SE$_m$(+-)	1.15	4.51	6.43	6.13
F-probability	***	***	***	*
CV,%	6.84	10.25	9.50	8.37
Grand mean	33.68	87.93	135.51	146.55

CV: coefficient of variation; DAS: days after sowing; NS: Non-significant; SE$_m$: standard error of the mean; *=significance level at 5% probability level, **= significance level at 1% probability level, ***= significance level at 0.1% probability level; LSD (0.05): Least significant difference at 5% level of significance same letter indicates the similar effect

Number of leaves per plant

There was no significant difference in the number of leaves per plant of maize due to different doses of phosphorus at different dates of observation (Table: 2).

Days of silking and tasseling

Different doses of phosphorus have significantly influenced the days to 50% silking and 50% tasseling (Table 3). The maximum number of days to 50% tasseling (65.51 days) and days to 50% silking (67.98 days) were taken at the treatment 40 kg P_2O_5 ha^{-1} which was statistically similar to the treatment 0 kg P_2O_5 ha^{-1} and a minimum number of days to 50% tasseling (56.81days) and 50% silking (59.8days) was reported with treatment 100kg P_2O_5 which is statistically similar with treatment 80 kg P_2O_5 ha^{-1}. Lower days in silking and tasseling might be due to increased vegetative development along with root development which helps the plant to take up and utilize phosphorus quickly (Amanullah, Zakirullah, & Khalil, 2010). However, these findings are not in line with Khan et al. (2014) who found that different doses of P_2O_5 have no significant influence on days to 50% silking and 50% tasseling of maize.

Table 2. Effect of different doses of phosphorus on the number of leaves per plant of spring maize (Arun-2) at Khaireni, Gulmi, 2022

Treatment	Number of leaves per plant			
	30 DAS	45 DAS	60 DAS	75 DAS
0 kg P_2O_5 ha^{-1}	5.25	7.54	10.61	12.43
20 kg P_2O_5 ha^{-1}	5.07	7.57	10.54	12.39
40 kg P_2O_5 ha^{-1}	5.50	7.36	10.43	12.75
60 kg P_2O_5 ha^{-1}	5.57	7.57	10.61	12.75
80 kg P_2O_5 ha^{-1}	5.14	7.43	10.43	12.54
100 kg P_2O_5ha^{-1}	5.36	7.50	10.50	12.40
LSD(0.05)	0.45	0.48	0.42	0.76
SE$_m$(+-)	0.15	0.16	0.14	0.26
F-probability	NS	NS	NS	NS
CV,%	5.62	4.24	2.64	4.10
Grand mean	5.32	7.49	10.52	12.54

CV: coefficient of variation; DAS: days after sowing; NS:Non-significant; SE$_m$:standard error of the mean; *=significance level at 5% probability level, **= significance level at 1% probability level, ***= significance level at 0.1% probability level; LSD(0.05):Least significant difference at 5% level of significance same letter indicates the similar effect.

Table 3. Effect of different doses of phosphorus on days to silking and tasseling of spring maize(Arun-2) at Khaireni, Gulmi, 2022

Treatments	Days to tasseling	Days to silking
0 kg P_2O_5 ha^{-1}	64.24^{a}	67^{a}
20 kg P_2O_5 ha^{-1}	62.07^{ab}	64.95^{a}
40 kg P_2O_5 ha^{-1}	65.51^{a}	67.98^{a}
60 kg P_2O_5 ha^{-1}	62.41^{ab}	65.75^{a}
80 kg P_2O_5 ha^{-1}	58^{b}	64.57^{ab}
100 kg P_2O_5 ha^{-1}	56.81^{b}	59.85^{b}
LSD(0.05)	5.75	4.82
SE$_m$(+-)	1.91	1.56
F-probability	*	*
CV,%	6.20	4.92
Grand mean	61.51	65.02

CV: coefficient of variation; DAS: days after sowing; NS: Non-significant; SE$_m$: standard error of the mean; *=significance level at 5% probability level; LSD (0.05): Least significant difference at 5% level of significance same letter indicates the similar effect.

Yield and yield attributing characters

Yield and yield attributing characters were found to be increased with increasing the dose of the phosphorus. The number of kernel rows per cob, number of grains per kernel, number of grains per cob, and grain yield were found to be maximum with 80 kg P_2O_5 ha^{-1} (6203.29kg ha^{-1}) which was statistically similar with 100kg P_2O_5 ha^{-1} (6033.20). Phosphorus at 0 kg ha-1 produced the fewest grains per cob (225.28) because phosphorus promotes healthy root development, which has a direct impact on

plant performance as a whole. Masood et.al (2011) has also mentioned similar results.

Cob length

Different doses of phosphorus resulted in a significant variation in cob length (Table 4). There is a positive relationship between doses of phosphorus and ear length. The longest cob was produced with higher doses as reported by Amanullah, Zakirullah, & Khalil, (2010), this may be due to the rapid increase in vegetative character. The longest cob length (23.05cm) was found with 100kg P_2O_5 ha^{-1} which was statistically at par (22.11cm) with 80kg P_2O_5 ha^{-1} and the smallest cob (17.47cm) was found with 0kg P_2O_5 ha^{-1} followed by 17.90cm, 19.75cm & 20.10cm with 20 kg P_2O_5 ha^{-1}, 40 kg P_2O_5 ha^{-1} & 60 kg P_2O_5 ha^{-1} respectively.

Number of kernel rows per cob

There was a significant variation in the number of kernel rows row per cob due to different doses of phosphorus (Table 4). The number of kernel rows (15.19) was recorded as maximum with 80 kg P_2O_5 ha^{-1} which was statistically similar to 100 kg P_2O_5 ha^{-1} (14.93). Minimum kernel rows (11.04) were recorded with 0 kg P_2O_5 ha^{-1}. The consequence of a higher rate of P_2O_5 in more kernel rows per cob could be due to Phosphorus positive response to rapid growth of maize (Sadiq, et al., 2017).

Number of grains per kernel row

The number of grains per kernel row was found to be increased with increasing the dose of the phosphorus (Table 4). The maximum number of grains per kernel (26.78) was found in a plot with 100kg P_2O_5 ha^{-1} which was statistically similar (26.35) with 80kg P_2O_5 ha^{-1}. The minimum number of grains per kernel row (20.22) was found with 0kg P_2O_5 ha^{-1}.

Number of grains per cob

There was significant variation due to different doses of phosphorus in the number of grains per cob of maize (Table 4). The highest number of grains per cob was found with 80 kg P_2O_5 ha^{-1}. An increase in the number of grains per cob might be due to better flowering and fruiting enhanced by phosphorus (Alias , Usman, Ullah, & Warraich, 2003). The application of 0kg P_2O_5 ha^{-1} resulted in minimum number of grains per cob. The result is in accordance with Khan et.al (2014), who has stated the significant influence of NP application on the number of grains per cob.

Thousand-grain weight

The effect of different doses of phosphorus on thousand-grain weight was not significant (Table 4). However, the maximum thousand-grain weight of 282 g was found in plots with 60kg P_2O_5 ha^{-1} followed by 275 g with 80 kg P_2O_5 ha^{-1}. For estimating grain yield, thousand grain weight plays a crucial role. The lowest thousand-grain weight 253 g was obtained in a plot with 40 kg P_2O_5 ha^{-1} followed by 255 g with 0kg P_2O_5 ha^{-1}. The highest thousand-grain weight could be due to maximum assimilates being transmitted to grains as mentioned by Sadiq et.al (2017).

Grain yield

The grain yield of maize as influenced by different doses of phosphorus is in the table (4). The data revealed that different doses of phosphorus significantly affected in grain yield as reported by Sadiq et.al (2017). An increment in dose of phosphorus up to 80kg P_2O_5 ha^{-1} has resulted in increased grain yield as maximum grain yield (6203.29 kg ha^{-1}) was obtained at 80kg P_2O_5 ha^{-1} followed by(6033.20 kg ha^{-1}) at 100kg P_2O_5 ha^{-1}. The lowest grain yield (3310.9kg ha^{-1}) was obtained at 0 kg P_2O_5 ha^{-1} followed by 3784.74 kg h^{-1} and 3831.18 kg ha^{-1} at 40 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} respectively. Masood et.al (2011) found significantly higher yields up to 100kg P_2O_5 ha^{-1}. Phosphorus application at the rate of 80kg ha^{-1} resulted in the highest number of rows per cob, the number of grains per cob, and thousand-grain weight which resulted in the highest grain yield at 80kg P_2O_5 ha^{-1}. Increasing Phosphorus above 80 kg ha^{-1} may be excessive, which has reduced the maize grain yield, indicating that the application of P_2O_5 in maize above 80 kg ha^{-1} is unreasonable in the mid-hill of Nepal. An adequate and ideal supply of P_2O_5 is linked to increased root growth, which encourages plants to inspect more of the soil's nutrients and moisture. Because of this, the grain yield with 0kg P_2O_5 ha^{-1} was the lowest because a lack of Phosphorus caused the plant's roots to grow more slowly, which had an adverse effect on the other physiological processes of those maize plants.

Harvest index

Different doses of phosphorus showed a significant effect on the harvest index of maize (Table 4). Phosphorus doses of 60 kg P_2O_5 ha^{-1}, 80kg P_2O_5 ha^{-1} had shown statistically similar harvest indexes i.e., 38.13 and 37.99 respectively, and the minimum harvest index was recorded at 0 kg P_2O_5 ha^{-1}. Better translocation of assimilates indicates a higher harvest index (Adhikari, Bhandari, Aryal, Mahato, & Shrestha, 2021). Alias, Usman, Ullah, & Warraich (2003) also reported a significant variation in the harvest index of maize due to different doses of phosphorus. However, Asim et.al (2017) and Iqbal & Chauhan (2003) reported a non-significant variation on the harvest index of maize due to different doses of phosphorus.

Shelling Percentage

Table 5 shows the effect of different dose of phosphorus on shelling percentage. Higher dose of phosphorus resulted in higher shelling percentages. Similar result was reported by Ali, Bakht, Shafi, Khan, & Shah (2002). Maximum shelling percentage (74.49%) was obtained with 100kg P_2O_5 ha^{-1} which was statistically similar at par with 80kg P_2O_5 ha^{-1}(73.05%) and the minimum shelling percentage (39.45%) was found with 0kg P_2O_5 ha^{-1}.

Table 4. Effect of different doses of phosphorus on yield attributes of spring maize (Arun-2) at Khaireni, Gulmi, 2022

Treatment	Cob length	Number of kernel row per cob	Number of grains per kernel row	Number of grains per cob	Thousand-grain weight (g)	Grain yield (kg ha^{-1})	Harvest index
0 kg P_2O_5 ha^{-1}	17.47^{c}	11.04^{b}	20.23^{b}	225.29^{b}	255.5^{a}	3310.98^{b}	29.19^{b}
20 kg P_2O_5 ha^{-1}	17.90^{c}	11.45^{b}	20.75^{b}	237.55^{b}	265.0^{a}	3831.18^{b}	29.37^{b}
40 kg P_2O_5 ha^{-1}	19.75^{bc}	11.72^{b}	22.90^{ab}	267.30^{b}	253.0^{a}	3784.74^{b}	32.73^{ab}
60 kg P_2O_5 ha^{-1}	20.10^{bc}	12.76^{ab}	23.35^{ab}	297.66^{b}	282.0^{a}	4500.77^{ab}	38.13^{a}
80 kg P_2O_5 ha^{-1}	22.11^{ab}	15.19^{a}	26.35^{a}	406.22^{a}	275.0^{a}	6203.29^{a}	37.99^{a}
100 kg P_2O_5 ha^{-1}	23.05^{a}	14.94^{a}	26.76^{a}	395.50^{a}	260.0^{a}	6033.20^{a}	32.73^{ab}
LSD(0.05)	2.93	2.84	3.99	19.79	38.10	974.14	6.56
SE_m(+-)	0.97	0.94	1.32	30.17	12.64	323.17	2.18
F-probability	**	*	*	**	NS	*	*
CV,%	9.70	14.68	11.32	19.79	9.54	14.01	12.85
Grand mean	20.06	12.84	23.39	304.92	265.08	4610.67	33.85

CV: coefficient of variation; DAS: days after sowing; NS: Non-significant; SE_m: standard error of mean; *=significance level at 5% probability level, **= significance level at 1% probability level; LSD (0.05): Least significant difference at 5% level of significance, same letter indicates the similar effect.

Table 5. Effect of different doses of phosphorus on shelling percentages of spring maize (Arun-2) at Khaireni, Gulmi, 2022

Treatments	Shelling %
0 kg P_2O_5 ha^{-1}	39.45^{c}
20 kg P_2O_5 ha^{-1}	40.03^{c}
40 kg P_2O_5 ha^{-1}	52.58^{c}
60 kg P_2O_5 ha^{-1}	56.37^{bc}
80 kg P_2O_5 ha^{-1}	73.05^{ab}
100 kg P_2O_5 ha^{-1}	74.49^{a}
LSD(0.05)	17.75
Grand mean	56

CONCLUSION

From this study, it was found that different doses of phosphorus affected the growth and yield of spring maize. The plant height, cob length, number of grains per kernel, and shelling percentage were highest in plants with 100 kg P_2O_5 ha^{-1}, while the number of kernel rows per cob, number of grains per cob, and grain yield were highest with 80 kg P_2O_5 ha^{-1}. Thus, for better growth along with the increment in yield of maize phosphorus at the dose of 80 kg is recommended as this dose has enhanced the growth and yield parameters of spring maize. However, for more accurate and considerable results multi location trials can be conducted as well as further research should be conducted in different seasons to validate these findings.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

Influence of chemicals and crude plant materials as pre-storage treatment on seed quality of onion

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ABSTRACT
Fresh onion seeds dried to 7.0% seed moisture content were stored with crude plant materials (red chili powder@20g/kg of seed; neem leaf powder@ 20g/kg of seed, lemon leaf powder @ 20g/kg seed), and chemicals (common bleaching powder and mancozeb @ 2g/kg of seed). The germination potential of onion seeds was found satisfactory in treated seeds. Water uptake during imbibition was maximum in lemon leaf treated seed which indicates better germination as the imbibition of water is an essential part of germination. A high correlation between EC measurements and germination was found; which indicates that conductivity readings have the potential to provide a rapid assessment of standard laboratory germination. In terms of seed-associated pathogens during storage, chemicals have shown better results in suppressing pathogens.
Keywords: Crude plant materials, Onion, Seed, Quality, Storage.

INTRODUCTION
Seed vigor consists of those properties, which conclude the potential for rapid uniform emergence and development of normal seedlings under a wide range of field conditions. The main factors affecting seed storage capability are the content of high temperature, ambient relative humidity, and seed moisture (Abdul-Baki, 1980). The loss of viability in onion seed is very fast, normally within a year (Singh and Bhonde, 2003).
This matter poses a serious problem to maintain the vigor and viability of onion seed for longer periods under ambient conditions. To prevent seed deterioration and better field performance Pre-storage dry seed invigoration treatments of stored onion seeds were found effective (Sengupta *et al*., 2005). The reason for the work had been on onion seed, the similar study was conducted at Crop Research and Seed Multiplication Farm, The University of Burdwan to evaluate the effect of various Seed invigoration treatments on germinability and field performance of onion (cv. Agri found Dark Red).
The onion (Allium cepa L.) is a crop of major economic and dietary importance in all parts of the world. Compared with many other crops, the onion has a fairly complex life cycle involving several distinct development phases. It is generally known that onion seed is one of the shortest-lived seeds of the common vegetable crops, rapidly losing viability after harvest unless special precautions are taken in its storage. It is therefore generally recommended that only fresh onion seed should be used for crop production (Riekels et al., 1976), and only seeds of high germination percentage should be sold. The percentage and rate of germination of onion seeds also vary considerably among seed lots (Bedford & MacKay, 1973) and this leads to difficulties in establishing optimum plant populations in the field. It has long been known that the factors, which have the greatest influence on the longevity of seeds in storage are moisture, temperature, and oxygen partial pressure. It is usually agreed that the moisture content of the atmosphere is the most critical factor, with a rise in air moisture being more damaging than rising temperatures. However, it has been recommended that dry and very dry seeds should be humidified before germination to raise their moisture contents slowly in the initial stages (Powell & Matthews, 1979; Ellis *et al*., 1985 a & b). Several other workers have also attempted to store the onion seeds under different storage conditions for

different periods (Caneppele *et al*., 1995; Pandey, 1996; Stumof *et al*., 1997; Yanping et al., 2000). Therefore, it becomes necessary to evaluate the physiological quality of commercially available onion (Allium cepa L.) seed stored for different periods for proper crop stand and performance in the field. In the present study, the experiment was conducted to find out possible ways to improve the storability of onion seeds by using crude plant materials and chemicals as a pre-storage seed treatment.

MATERIALS AND METHODS

Seed source and storage:

Seeds of onion (*Allium cepa* L.) variety BARI Piaj-1 was obtained in April 2020 from the research field of Seed Technology Division, Bangladesh Agricultural Research Institute, Gazipur. After collection, seeds were cleaned and dried in the sun for 5–6 days to a moisture content of 7.0 % for safe storage. Seeds were then stored in the 500ml capacity rubber stopper glass bottles under ambient conditions in the laboratory till seed invigoration treatment. After cleaning and drying seeds were divided into six lots for Pre-storage seed invigoration treatments. After treatments seeds were stored in a 100 ml. capacity test tube, each containing 50 g seeds. The test tubes were then air-tied primarily with aluminum foil paper and covered again with polythene to control moisture absorption of the treated seed.

Onion seeds were dry-dressed with crude plant material, viz. neem leaf powder (*Azadirachta indica* L.) at 20g/kg of seed, red chili powder (*Capsicum frutescens* L) at 20g/kg of seed, lemon leaf powder (*Citrus limon* L.) at 20g/kg of seed, and chemicals viz. mancozeb at 2 g/kg and bleaching powder at 2g/kg of seed in an airtight test tube at room temperature. After treatment, test tubes were shaken twice a day for up to 7 days for thorough mixing of crude plant materials and chemicals with the seeds, and the test tubes were kept in the laboratory under ambient conditions (25-300 C).

Determination of seed moisture content:

Three replicate samples, each of 1000 seeds were taken and weighed, evenly spaced in 90 mm glass Petri dishes and placed in an oven at 103±2°C for 17 ± 1 h, cooled in a silica gel container for 15–30 min, after which they were reweighed. The moisture content was expressed as a percentage of their wet weight in accordance with the International Rules for Seed Testing (ISTA, 1985) and calculated as:

Percentage moisture content (%MC.) = $\frac{M2-M3}{M2-M1} \times 100$

Where, M1 is the weight of the dish, M2 is the weight of the dish and its contents before drying and M3 is the weight of the dish and its contents after drying.

Water uptake during the imbibition period:

Seed samples were counted, weighed, and then imbibed in Petri dishes on double sheets of filter paper moistened with 10 mL of distilled water in ambient conditions at 25±2°C. Dishes were removed from the series at intervals, and the seeds were drained and surface water removed by blotting between sheets of paper towel. The seeds were then immediately weighed, and the percentages of water taken up were recorded and calculated as:

Percentage water uptake = $\frac{W1-W2}{W2} \times 100$

Where,

W1 is the weight of the seeds after imbibition and

W2 is the weight of seeds before imbibition.

Germination test:

The germination potential of the onion seeds was estimated (ISTA, 1985). Germination percentages, using four replicates of 100 seeds, were determined by placing the seed samples in 120 mm Petri dishes on filter papers (Whatman No. 1) moistened with 3 mL of distilled water. Seeds were distributed evenly within each dish. Petri dishes were covered with their lids and then placed in a germination room, maintained at 20±2°C temperature. Each Petri dish was watered daily with an amount of distilled water according to its requirement. The first counting of germination was recorded on the 6th day and the final counting was recorded on the 12th day. The germination percentage was recorded by the following formula

Germination percentage = $\frac{Number\ of\ seeds\ germinated}{Number\ of\ seeds\ placed\ for\ germination} \times 100$

The following recognizable abnormalities of onion seedlings were recorded as abnormal seedling, as listed in Section 5.8.2 (ISTA, 1966).

Ia - no primary root

Ib - primary root short and stunted Ic primary root short and weak or spindly

IVc - poorly developed leaf-like cotyledon without a definite bend or "knee"

Va - decayed cotyledon

Ve - decayed primary root

Vg - completely decayed seedling (an additional category to those in Section 5.8.1)

VIa - short and weak, or spindly, or watery seedling

Electrolyte leakage:

Solute leakage of treated seeds was estimated by placing triplicates of 2 g seeds each in 20 ml of distilled water for 12 h at 25^0C. Electrical conductivity of the medium was measured with a conductivity meter (Model EC-407L, NeoMet., USA).

Tetrazolium viability test:

1g of 2,3,5-triphenyl tetrazolium chloride (TTC) was dissolved in 100 mL of distilled water to make a 1% solution of the tetrazolium salt. The test was conducted with two replicates of 100 seeds soaked in distilled water for 18 - 20 h. Each seed was cut longitudinally without completely separating the two halves. The seeds were submerged in 1% TTC solution for at least 8 h at 25°C in darkness, after which the staining patterns were recorded.

Seed health:

A total of six different treatments (viz. T_1= lemon leaf powder, T_2= neem leaf powder, T_3= red chili powder,

T_4= mixture of T_1, T_2 & T_3, T_5= bleaching powder, T_6= Mancozeb) along with control were applied to assess the quality of onion seeds in storage. The prevalence of seed-associated pathogens was identified in two different ways; a) growing treated seeds in PDA plates, b) growing untreated seeds in PDA plates prepared with treatment elements. Pathogens were observed after 72 hours of incubation at 25ºC. The prevalence of pathogens was documented from different treatments.

RESULTS AND DISCUSSION

Moisture content of seeds after storage:

The initial moisture of the seed was 7.0%. Seeds were stored after harvesting for up to the next growing season for 8 months.

Replicate samples of the onion seeds of different treatments were withdrawn from the test tube in which they had been stored. These were weighed, and their water contents were determined on a dry-weight basis (ISTA, 1985). The lowest moisture content (7.24%) was recorded when the seed was treated with lemon leaf powder which was probably due to the high absorption ability of lemon leaf powder from the air and the highest moisture content (9.17%) was recorded when the seed treated with Mancozeb which was statistically identical to the moisture content of seeds treated with red chili powder. The moisture content of the other seed treatments varied from 7.43-7.97% (Table 1).

Moisture content and water uptake during imbibition:

Replicate samples of onion seeds were tested for their moisture contents and the amounts of water required for full imbibition were determined. The results presented in Table 1, show that the seed moisture content after imbibition differs among the seed lots tested. However, the percentages of water taken up did not differ depending upon the seed lot (different seed treatments). Water uptake during imbibition was maximum (50.89%) in lemon leaf treated seed, which contained the lowest moisture content before imbibition. The minimum water uptake (44.08%) was recorded in the untreated seed. Treatments and initial moisture content (after storage) of seeds may cause differences in the process of imbibition, and the amount of water required for the initiation of metabolism and germination. The imbibition of water into the dry seed is an essential part of germination; which has also been documented as a potentially hazardous period (Woodstock, 1988). The imbibition of water converts the seed from a quiescent body with a very low or non-detectable respiratory rate into a metabolizing organism, active in respiration and in biosynthesis, and capable of growth (Mayer & Poljakoff-Mayber, 1974). The amounts of water taken up by the seeds during imbibition prior to germination in the present study appeared within the expected range depending on their initial moisture contents (Table 1).

1000 seed weight before and after imbibition:

1000 seed weight before and after imbibition did not vary significantly among the treatments. The lowest (2.996 g) 1000 seed weight before imbibition was recorded in T6 (mixture of leaves) and the highest (3.047 g) was recorded in T1 (bleaching powder) treatment. The lowest (4.328g) 1000 seed weight after imbibition were recorded in untreated seed and the highest (4.568g) was recorded in T4 (neem leaf powder) treatment (Table 1).

Table 1. Initial moisture content and extra water are taken up during imbibition of onion seeds of different treatments stored at ambient conditions.

Pre-storage seed invigoration treatment	% moisture before imbibition	% Moisture after imbibition	Water uptake (%)	1000 seed wt. (g) before imbibition	1000 seed wt. (g) after imbibition
Bleaching Powder	7.97	38.01	48.52	3.0477	4.525
Mancozeb	9.17	39.61	49.51	3.021	4.515
Red Chilli Powder	9.13	39.99	46.78	3.046	4.4713
Neem Leaf Powder	7.57	39.71	49.20	3.062	4.5687
Lemon Leaf Powder	7.24	42.74	50.89	3.0207	4.558
Mixture of leaves	7.43	38.23	47.84	2.9967	4.4303
Control (Untreated)	7.92	37.70	44.08	3.005	4.328
LSD 5%	* (0.57)	* (1.96)	NS	NS	NS
CV (%)	4.05	2.85	11.61	1.41	3.42

*Values are the means of four replicates, each of 1000 seeds (Initial moisture of seed during storage was 7.0%)

Seed viability:

Samples of the seeds from the different treatments available were subjected to the tetrazolium test. The seed samples tested showed good viability. The highest viability was recorded when the seeds were treated chemically (97% and 96% viability in bleaching powder and mancozeb respectively). (Table 2)

The tetrazolium test is a biochemical test, which differentiates the living and dead tissues of seed by the presence or absence of a red stain known as formazan. A germination test can give an apparently erroneous result because some seeds may be in a state of dormancy, but the tetrazolium test includes all the seeds, which are alive either active or dormant (Porter *et al*., 1947)

Germination test (Normal seedling, abnormal seedling, and dormancy):

Laboratory germination tests are performed in optimum conditions, but field conditions are seldom optimal. Some indications of the probable performance of a seed lot in the field may be obtained by subjecting the seeds to some degree of stress before or during the laboratory germination period. A comparison of germination percentages in Tables II shows that seed from all treatments had slightly changed their relative positions (initial germination percentage before storage was 99%) with the best performance in the germination test (86%) shown in the lemon leaf powder treated seed. Seeds treated with neem leaf powder, a mixture of leaves, and

bleaching powder were in the middle, and seeds stored with mancozeb and without any treatment gave the poorest performance. Seedling abnormalities vary slightly with the treatments. The highest abnormalities were recorded in the seedlings resulting from treatment T6 (mixture of leaves) and the lowest in the T4 treatment (Mancozeb). Abnormalities were similar to those from all other treatments. Considering the level of dormancy chemically treated seeds showed the highest dormant condition (17% and 16% in bleaching powder and mancozeb, respectively). This might be due to some chemical interactions between the treatments along with the seed. Seed treated with lemon leaf powder and neem leaf powder resulted in the lowest (5% and 6%, respectively) dormant condition of the seed. (Table 2).

Table 2. Germination potential after twelve days of germination

Pre-storage seed invigoration treatment	Viability (tetrazolium test)	Number of Normal Seedling	Number of abnormal Seedling	Dormancy
Bleaching Powder	97	74	6	17
Mancozeb	96	77	3	16
Red Chilli Powder	90	75	5	10
Neem Leaf Powder	92	80	6	6
Lemon Leaf Powder	94	83	6	5
Mixture of leaves	90	75	8	7
Control (Untreated)	90	72	5	13
LSD 5%	5.96	4.58	2.78	1.79
CV (%)	3.66	3.41	27.57	9.86

*Figures are the means of four replicates of 100 seeds for germination test, and two replicates of 50 seeds each for tetrazolium test.

Fully stained seed	Partially stained seed	Dead seed/ Non-viable

Fig. 1. Different stained condition of onion seed after viability test

Fig. 2. Different types of abnormal seedlings of onion that were found at the period of last counting days of germination test

The close relationship between the EC of different treatment's germination percentages was illustrated in Figure 3. The highest (1087µs/cm) solute leakage was recorded in the untreated seed which indicates the lowest germination percentage which was statistically identical with the chemically treated seeds. And the lowest (914µs/cm) solute leakage was recorded in T5 treatment (Lemon leaf powder) which was statistically identical with all the treated seeds of crude plant materials. (Fig 3)

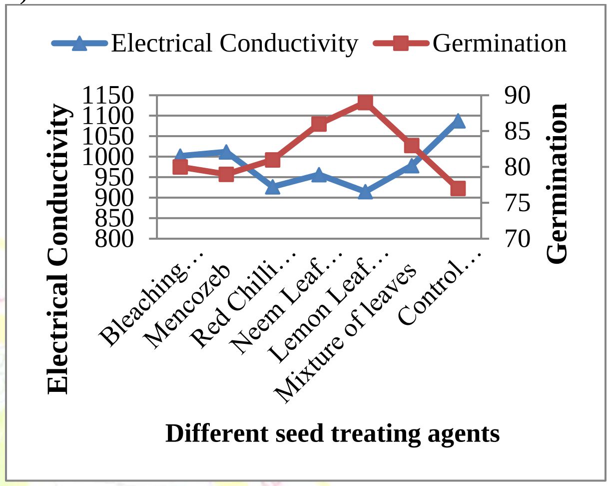

Fig. 3. Relationship between electrical conductivity and germination percentage

The relation between solute leakage and normal germination percentages was highly negative in all treatments. This shows that conductivity detects that the germination differences among the treatments. We measured the leakage of all treated seed samples measuring the overall mean of all seed leakage. Obviously, higher solute leakage would occur in samples with a high proportion of dead seeds (low germination percentages). Demir et al., 2008 and Mavi et al., 2016 were also reported that the average conductivity reading per gram seed weight in the bulk conductivity method is successful.

A high correlation between EC measurements, germination, and dead seeds indicates that conductivity readings have the potential to provide a rapid assessment of standard laboratory germination. Information about the standard germination percentages of any lot can be obtained within 24 hours, compared to the 12-day germination test in this work for cress.

It is easy to correlate directly germination with solute leakage and germination with the tetrazolium test. But it is highly difficult to correlate these three parameters. In our experiment, we have found a high EC value in chemically treated seeds which indicates a low germination percentage, more precisely which indicates more dead seeds. But in the tetrazolium salt test, these two treated seeds showed high value, which indicates having minimum dead seeds. So, it can be concluded like that, EC test will provide an assessment of germination but cannot provide the assessment of dead seeds.

CONCLUSION

On account of our experimental observations, it could be concluded that pre-storage seed treatment with lemon leaf powder is an appropriate corrective measure to be chalked out to maintain the germination potential of onion seeds during storage.

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Research Article

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Effect of physical treatments on phenolics and tannins in *Ficus roxburghii* and *Quercus leucotrichophora* leaves

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ABSTRACT
Inadequate availability of straws and conventional concentrates is one of the major constraints for rearing large and small ruminants. Alternative or unconventional fodder resources play a supplementary role in meeting the demand of livestock owners; but these tree leaves contain some antinutritional factors. Tremal (*Ficus roxburghii)* and Oak (*Quercus leucotrichophora)* are among the traditional tree fodder sources available in the North Western Himalayan region. Their use a feed stuff for livestock is limited due to presence of tannis. So, the study was undertaken to assess the effect of different physical treatments on total phenol and tannin fractions of Tremal and Oak leaves. Fresh leaves lopped from Tremal and Oak trees of Kangra district of Himachal Pradesh were subjected to physical treatments like chopping and sun drying after chopping. The phenol and tannin fractions of these leaves were estimated before and after treatment. Total phenols, total tannin and hydrolysable tannin contents of the *F. roxburghii* and *Q. leucotrichophora* leaves were reduced significantly (P<0.0001) by both the physical treatments. However, both the treatments increased (P ≤ 0.0001) the condensed tannin content of *F. roxburghii* leaves, whereas chopping followed by sun drying also increased the non-tannin phenol contents. Both the treatments were effective in reducing tannin contents (both hydrolysable and condensed) of *Q. leucotrichophora* leaves. It may be concluded that physical treatments, chopping, chopping and sun drying, were though effective in reducing hydrolysable tannins, but were not effective in reducing condensed tannin contents of *F. roxburghii* leaves; whereas chopping, chopping and sun drying were effective in reducing tannin contents in case of *Q. leucotrichophora* leaves.
Keywords: Physical treatments, *Ficus roxburghii* leaves, *Quercus leucotrichophora* leaves, Tannins, Antinutritional factors.

INTRODUCTION

Lack of adequate year-round feed resources is one of the most important factors contributing to low animal production (Bhar *et al*., 2014; Kawas *et al.*, 2010). A well-known constraint to livestock rearing in the North West Himalayan Region of India is inadequate availability of conventional feed resources like concentrates, straw and cultivated green fodder. In Himachal Pradesh there exists a shortage of dry and green forages to the extent of 35.0 and 57.0%, respectively. In this context, fodder trees are of great importance as a major feed resource, especially, during lean period (Jiban, 2000 and Bhar *et al*., 2017).

Development of alternate complete feeds out of locally available feeds may partially alleviate the problem of animal feeding. Locally available processed tree leaves with optimum level of anti-nutritional factors could be incorporated in complete feed mixture of small and large ruminants. However, most of the tree leaves available in the region contain varying amounts of anti-nutritional factors viz. tannins, saponins, alkaloids etc. which limits their use as feedstuff for livestock.

Tremal (*Ficus roxburghii)* is one of the tree forages, which is available in plenty in upland areas. *F. roxburghii* leaves contain 87.64% Organic Matter (OM), 13.81% Crude Protein (CP), 4.33% Ether Extract (EE), 13.08% Crude Fibre (CF), 56.42% Nitrogen Free Extractives (NFE), 12.36% ash; and 5.10% Total Phenols (TP), 4.50% Total Tannins (TT), 0.90% Hydrolysable Tannis (HT) and 4.20% Condensed Tannins (CT) (on DM basis) (Devarajan, 1999 and Bharatbhusan M, 2012). Sharma, *et al*., 2000 reported the values of CP, EE, CF, TA and NFE in *F. roxburghii* on DM basis as 12.70, 4.79, 13.59, 21.74 and 47.18%, respectively.

Oak (*Quercus leucotrichophora)* is one of the tree forages and evergreen tree found in the Himalayas.

Leaves have dense white-woolly hairs on the underside with a greenish-white underside. The species name *leucotrichophora* means carrying white hairs. The flowers come out in catkins (slim cylindrical flower clusters). The acorns are said to contain a peanut like core when broken (Parmar and Kaushal, 1982). Leaves contain 9.56% CP, 4.8% EE, 31.30% CF, 18.40% NFE and 5.2% total ash on DM basis (CSIR, 1969). The values of OM, CP, EE, CF, NFE and total ash (on DM basis) in *Q. leucotrichophora* have been reported to vary from 91.89-95.43, 8.09-10.73, 2.45-5.38, 13.46-36.67, 48.40-49.50 and 4.76-20.19%, respectively (Sen *et al*., 1978; Sinha *et al*.,1989; Singh *et al*.,1999; Devarajan,1999; Anandan and Dey, 2000; Bharatbhusan., 2012; Ajith, 2012; Ajith *et al*., 2014). The TP, TT, HT and CT in *Q. leucotrichophora* in per cent (on DM basis) have been reported as 5.00, 3.70, 1.30 and 4.25, respectively (Devarajan, 1999).

Tannins reduce voluntary Dry Matter intake, cell wall digestibility, growth rate and true digestibility of protein. Tannins also exert inhibitory effects on growth and activity of rumen microbes. These polyphenols are reported to bind with epithelial proteins and proteins in the gut wall causing liver damage and preventing nutrient uptake. All these factors inhibit growth and productivity of animals grazing tannin rich forages. Therefore, the present study was undertaken to study the effect of different physical treatments on total phenol and tannin fractions of *F. roxburghii* and *Q. leucotrichophora* leaves (Devarajan,1999, Anandan and Dey, 2000, Bhar *et al*., 2017).

MATERIALS AND METHODS

The fresh mature tree leaves of *F. roxburghii* and *Q. leucotrichophora* were manually lopped from local forest area of Kangra District. Efforts were made to collect the leaves from the same tree to avoid the variability of leaves in stage of maturity, chemical composition and tannin content. Leaves were packed in gunny bags, brought to the Institute for various physical treatments. Leaves were divided into 4 parts as Fresh Untreated leaves [Control], Chopped [CL], Chopping and sun drying (for 3 days) [CSD] and chopping, sun drying (for 3 days) and grinding [CSDG] each containing 2.5 kg, for physical processing. The total phenol and tannin fraction of fresh leaves and treated leaves were estimated. The chemical composition of the leaves was determined by the methods of AOAC (2000), while fibre fractions were analyzed as per Van Soest *et al*. (1991). Condensed tannin and other fractions of tannins were estimated as per the method described by Makkar (2003). The data obtained were analysed by using SAS software (SAS, 2003).

RESULTS AND DISCUSSION

Chemical composition of tree leaves: The values of different proximate principles, cell wall and mineral constituents are presented in the table 1. The OM (Organic Matter), CP (Crude Protein), EE (Ether extract), TCHO (Total Carbohydrate), NDF (Neutral Detergent fibre), ADF (Acid Detergent Fibre), cellulose, hemi cellulose, total ash, calcium and phosphorous contents of Q. leucotrichophora (% on DM basis) were 94.02, 10.53, 4.02, 79.47, 48.89, 31.51, 20.54, 17.38, 5.98, 1.89 and 0.27, respectively; of F. roxburghii (% on DM basis) were 92.38, 13.86, 4.34, 74.18, 60.78, 52.72, 36.80, 8.06, 7.62, 2.38 and 0.22, respectively.

Table1. Chemical composition of tree leaves:

Attributes	Tree leaves	
	Q. leucotrichophora	***F. roxburghii***
Proximate Composition		
OM	94.02	92.38
CP	10.53	13.86
EE	4.02	4.34
TCHO	79.47	74.18
Cell wall constituents		
NDF	48.89	60.78
ADF	31.51	52.72
Cellulose	20.54	36.80
Hemi cellulose	17.38	8.06
Minerals		
Ash	5.98	7.62
Calcium	1.89	2.38
Phosphorous	0.27	0.22

Effect of physical treatments on different polyphenols of *F. roxburghii:*

Effect of physical treatments on different polyphenols of *F. roxburghii* leaves is presented in Table 2. Total phenol (TP), non-tannin phenol (NTP), total tannin (TT), condensed tannin (CT) and hydrolysable tannin (HT) content (% DM basis) of fresh *F. roxburghii* leaves were 6.27 ± 0.17, 1.12± 0.01, 5.15± 0.17, 1.63± 0.04 and 3.52 ± 0.18, respectively. In chopped leaves these polyphenols were 5.18, 1.08, 4.10, 1.86 and 2.24 %; in CSD leaves 5.40, 1.29, 4.11, 1.78 and 2.32 %; where as in CSDG leaves these were 5.34, 0.38, 4.95, 1.62 and 3.33 %, respectively.

All the polyphenols were reduced ($P < 0.0001$) in all the physical treatments (chopping, CSD and CSDG). However, the extent of reduction differed from one polyphenol to other and from one treatment to other physical treatment. TP was reduced to the maximum extent (17.35 %) due to chopping, followed by the other two treatments, CSD and CSDG, difference between which were not significant. The NTP and CT were reduced to the maximum extent due to CSDG; whereas the extent of reduction in TT and HT was maximum due to chopping and followed by CSDG, differences between the treatments chopping and CSD being non-significant. Both the physical treatments, chopping (T_2) and chopping & sun drying (T_3), significantly ($P<0.0001$) reduced total phenol, total tannin and hydrolysable tannin content (% DM basis) of *F. roxburghii* leaves (Table 2). However condensed tannin content significantly ($P<0.0001$) increased in both the treatments. Though chopping reduced ($P<0.0001$) non-

tannin phenol content, chopping and sun drying increased it.

Table 2. Effect of physical treatments on different phenol contents of *Ficus roxburghii* leaves.

Physical Treatments	Total phenol	Non tannin phenol	Total tannin	Condensed tannin	Hydrolysable tannin
Fresh	6.27^{A} ± 0.17	1.12^{B} ± 0.02	5.15^{A} ± 0.17	2.33^{A} ± 0.01	2.82^{B} ± 0.17
Chopped	5.18^{B} ± 0.02	1.08^{B} ± 0.01	4.10^{B} ± 0.02	1.86^{B} ± 0.01	2.24^{C} ± 0.02
Chopped sun dried (CSD)	5.40^{B} ± 0.02	1.29^{A} ± 0.01	4.11^{B} ± 0.02	1.78^{C} ± 0.003	2.32^{C} ± 0.01
Chopped sun dried grinded (CSDG)	5.34^{B} ± 0.01	0.38^{C} ± 0.04	4.95^{A} ± 0.05	1.62^{D} ± 0.12	3.33^{A} ± 0.05
Overall mean ± SE	5.55 ± 0.12	0.97 ± 0.09	4.58 ± 0.13	1.90± 0.07	2.68 ± 0.12
P Value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Per cent reduction on physical treatment					
Chopped	17.35^{a} ± 0.38	3.81^{b} ± 0.47	20.29^{a} ± 0.37	20.03^{c} ± 0.06	20.51^{a} ± 0.73
Chopped sun dried	13.90^{b} ± 0.37	-15.32^{c} ± 0.64	20.26^{a} ± 0.46	23.51^{b} ± 0.23	17.57^{a} ± 0.75
Chopped sun dried ground	14.83^{b} ± 0.23	65.63^{a} ± 0.68	3.79^{b} ± 1.01	30.27^{a} ± 0.65	-18.09^{b} ± 1.60
Overall mean ± SE	15.36 ± 0.47	18.04 ± 10.48	14.78 ± 2.37	24.60 ± 1.30	6.66 ± 5.32
P Value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

*Means bearing different superscripts with in a column (A, B, C/a,b,c etc,) differ significantly ($P < 0.0001$).

All the polyphenols were reduced ($P < 0.0001$) in all the physical treatments (chopping, CSD and CSDG). However, the extent of reduction differed from one polyphenol to other and from one treatment to other physical treatment. TP was reduced to the maximum extent (17.35 %) due to chopping, followed by the other two treatments, CSD and CSDG, difference between which were not significant. The NTP and CT were reduced to the maximum extent due to CSDG; whereas the extent of reduction in TT and HT was maximum due to chopping and followed by CSDG, differences between the treatments chopping and CSD being non-significant. Both the physical treatments, chopping (T_2) and chopping & sun drying (T_3), significantly ($P<0.0001$) reduced total phenol, total tannin and hydrolysable tannin content (% DM basis) of *F. roxburghii* leaves (Table 2). However condensed tannin content significantly ($P<0.0001$) increased in both the treatments. Though chopping reduced ($P<0.0001$) non-tannin phenol content, chopping and sun drying increased it.

Effect of physical treatments on different polyphenols of *Q. leucotrichophora* leaves:

Effect of physical treatments on different polyphenols of *Q. leucotrichophora* leaves is presented in Table 2. Fresh *Q. leucotrichophora* leaves contained 7.26 % total phenols (TP), 1.12 % non-tannin phenols (NTP), 6.15 % total tannins (TT), 1.62 % condensed tannins (CT) and 4.52 % hydrolysable tannins (HT). All the physical treatments [chopping, chopping and sun drying (CSD), chopping sun drying and grinding (CSDG)] were effective ($P < 0.0001$) in reducing all, the phenolic contents in oak leaves (Table 3).

Table 3. Effect of physical treatment on phenolic contents (% on DMB) in *Q. leucotrichophora* leaves (Comparision between 3 treatments)

Physical Treatments	Total phenol	Non tannin phenol	Total tannins	Condensed tannins	Hydrolysable tannins
Fresh	7.26^{A} ± 0.03	1.12^{A} ± 0.01	6.15^{A} ± 0.04	1.62^{A} ± 0.02	4.52^{A} ± 0.06
Chopped	4.96^{C} ± 0.02	1.08^{B} ± 0.01	3.88^{C} ± 0.02	1.41^{B} ± 0.01	2.47^{C} ± 0.02
Chopped sun dried (CSD)	5.16^{B} ± 0.02	1.04^{C} ± 0.01	4.12^{B} ± 0.02	1.39^{B} ± 0.003	2.73^{B} ± 0.01
Chopped sun dried ground (CSDG)	4.30^{D} ± 0.05	1.02^{C}± 0.005	3.27^{D} ± 0.05	1.38^{B} ± 0.002	1.89^{D} ± 0.05
Overall mean ± SE	5.42 ± 0.23	1.06 ± 0.008	4.35 ± 0.23	1.45 ± 0.02	2.90 ± 0.21
P Value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Per cent reduction on physical treatment					
Chopped	31.73^{b}± 0.25	3.77^{b}± 0.46	36.93^{b} ± 0.30	12.86^{b}± 0.50	45.42^{b} ± 0.52
Chopped sun dried (CSD)	28.91^{c} ± 0.24	7.26^{a} ± 0.46	32.96^{c} ± 0.27	14.03^{a} ± 0.17	39.60^{c} ± 0.33
Chopped sun dried ground (CSDG)	40.76^{a} ± 0.68	8.18^{a} ±0.45	46.79^{a} ± 0.75	14.83^{a} ± 0.13	58.13^{a} ± 0.1
Overall mean ± SE	33.80 ± 1.25	6.40 ± 0.52	38.89 ± 1.44	13.90 ± 0.26	47.72 ± 1.91
P Value	< 0.0001	< 0.0001	< 0.0001	0.002	< 0.0001

*Means bearing different superscripts with in a column (A, B, C) differ significantly ($P <0.0001$)

Comparision of effects in polyphenols of *F. roxburghii* and of *Q. leucotrichophora* leaves:

All the physical treatment was effective in reducing all the polyphenols (Table 2 and 3). However, present reduction varies from one polyphenol to other. In *F. roxburghii* maximum overall reduction was of CT (ie 24.60%) followed by NTP (18.04%), TP (15.36%), TT (14.78%) and was lowest of HT (6.66%). Whereas in case of *Q. leucotrichophora* maximum reduction on physical treatment was of HT (47.72%) and lowest was of NTP (6.40%). This was obviously due to the difference in the nature of polyphenols between the plant species. Both the nature and quantity of polyphenols differ greatly between plant species (Synge, 1975).

Chopping significantly reduces all the polyphenols; chopping followed by sun drying further reduces CT and HT. Whereas, NTP was increased (P<0.0001) on sun drying of chopped leaves, but initial reduction of TT and HT of chopped leaves was further increased on sun drying and grinding. It seems that rate of oxidation of polyphenol differs from one polyphenol to other; which in turn changes the proportion of polyphenols on DM basis. Moreover, there was respiratory loss of Organic matter or sugars till the plant cells were dried. Among the polyphenols, the percentage of NTP in fresh *F. roxburghii* leaves was lowest and the quantitative proportion was only 1.12%, which increased to 1.29% on chopping, followed by sun drying. This increase was probably due to reduction of dry matter or soluble sugars due to respiratory loss (Mullen and Koller, 1988). The percentage increase or decrease of respective polyphenols, in respective physical processing of leaves may be due to differences in the rate of losses between polyphenols and soluble sugars or other organic matter/dry matter. Rate of losses of organic matter either as polyphenols or other soluble sugars or dry matter may vary between the three processes of losses. i.e., Due to oxidation of polyphenols; Due to respiration till drying and Due to physical processing (Mullen and Koller, 1988; Makkar, 2003; Bensalema *et al*., 2005; Vitti *et al*., 2005).

It is revealed that the reduction of polyphenols is proportional to the particle size of the leaves. Chopping facilitated the oxidative enzymes. Grinding increases the surface area, which in turn accelerated the oxidation and de-naturation of the poly phenols. Moreover, it was revealed that the degree of susceptibility to oxidative enzyme varies from one polyphenol to other. It seems that the degree of susceptibility of HT to oxidative enzyme is relatively more than the other polyphenols (Haslam,1966; Bagheripour *et al*., 2008). Effect of physical treatment on reduction of polyphenols, however, reported to be variable from one feed to other, and also from one polyphenol to other. Makkar and Singh (1993) did not observe any effect on TP and CT on drying of mature oak leaves. However, Makkar and Singh (1991) reported that drying was effective for the feed stuffs having high moisture content. Bensalema *et al* (1999) reported that sun drying was more effective in reducing CT in acacia foliage than shade drying.

CONCLUSION

It may be concluded that all the physical treatments-chopping, chopping & sun drying, chopping, sun drying and grinding were effective in reducing hydrolysable tannin, were not effective in reducing phenolic constituents like Total phenol, non-tannin phenol, Total tannins, Condensed tannins and Hydrolysable tannins. Hence after the physical treatment, these tree leaves can be used as a fodder resource for livestock sector in scarce and draught areas.

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Research Article

Evaluation on the efficacy of different chemical fungicides against rice blast *(Pyricularia oryzae*) under field condition at Siraha, Nepal

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ABSTRACT
Rice blast (*Pyricularia oryzae*) is a serious disease which hampers production of rice. The field research was conducted in PMAMP, PIU, Siraha Dhangadimai-10, Kuduwa to evaluate the efficacy of various chemicals against rice blast. The experiment was carried out in Completely Randomized Block Design (RCBD) with 7 treatments (6 chemicals and 1 control) and each treatment was replicated 3 times. Chemicals namely Hexaconazole5%(SC), Carbendazim12%+ Mancozeb 63%(WP), Azoxystrobin 18.2 % + Difenoconazole 11.4% (SC), Thiophonate-Methyl 70%wp, Kasugamycin 2% Wp and Floxystrobin+tubuconazole were used for this experiment. Azoxystrobin18.2 % + Difenoconazole 11.4 % (SC) was recorded as the best chemical followed by Carbendazim12%+Mancozeb 63%WP to control rice blast. The highest disease severity was seen at the control plot. The highest yield was observed in plot with Azoxystrobin+Difenconazole (5.16mt/ha) followed by Carbendazim12%+ Mancozeb 63%WP(5.12mt/ha).
Keywords: *Pyricularia oryzae*, Disease, Severity, Fungicides, Control, Yield

INTRODUCTION

In global scenario, more than one-third of people rely on rice for their daily meals. Rice is the primary staple food in Asia and the Pacific regions due to 39% of calories obtained from it (Yaduraju and Rao 2013).More than 80% of the population in Asian nations eats rice every day as a staple food(Hajano and Rajput 2011). With 1.49 million ha and a total production of 5.0 million tons in Nepal, rice is the most widely grown crop, with a productivity of 3.4 t ha^{-1} (Ghimire et al. 2019). Rice can be grown in a wide range of environment; from tropical plains to the foot of the mountain (Sabin et al. 2016). Rice productivity is low for a number of reasons such as inconsistent rainfall, drought, weeds, insect pest diseases, a lack of high-quality seeds, and a failure to use suggested production and plant protection techniques. One of the most significant diseases affecting rice is rice blast, caused by the fungus *Pyricularia oryzae*(Acharya et al. 2020). In Nepal, this disease was first detected in 1966. Although, rice blast is pervasive all over the rice growing regions in the country, it is quiet severe in valleys, river basins, foothills, and hills of Nepal(Magar, Acharya, and Pandey 2015a). All stages of rice growth are threatened by this disease. The pathogen spreads disease to most of the aerial parts of the plant causing lesions on them, including the leaf blade, leaf sheath, collar region, stem, panicle, and grain (hull), and also limits yield potential in disease-prone environments (Neupane & Bhusal , 2020).

Globally, blast disease accounts for 70 to 80 % reduction in yield of rice damaging vegetative as well as reproductive stages (Rijal and Devkota 2020). In Nepal, the disease reduces yield by 10-20% in susceptible varieties, but in severe cases yield reduction can reach upto 80%(Acharya et al. 2019). In an areas where rice is grown, a blast outbreak could result the crop loss from 35 to 50% and in a significant breakout of the disease, up to 100% of the crop could be lost (E.Tollen, 2013).As a result, a suitable, efficient, and economically viable method of chemical control is required for the sustainable production of rice.

MATERIALS AND METHODS

Experimental site

This experiment was carried out in the farmer’s field of Dhangadimai-10 Kuduwa, Siraha from Falgun 2077 to Ashad 2078. It is located at 26.7781° N latitude and 86.3655° Elongitude. During the experimental period the maximum temperature, relative humidity, and rainfall was33^{O} C,82%, and 553 mm respectively, whereas the minimum temperature, relative humidity and total rainfall was 23^{O}C, 53%, 128 mm respectively.

Experimental design and treatment combination

The experiment was carried out in a randomized complete block design (RCBD) maintaining three replic ations of seven treatments where each plot size was 3.5 m × 3.75 m. The distance between two blocks and two plots was 0.75cm and 0.5m respectively.

Table 1. Treatment with different fungicides used in the study

Treatment	Trade name	Common Name	Dose
T1	Krizole+5	Hexaconazole 5% SC	3ml/ltr
T2	Sixer	Carbendazim 12 % + Mancozeb 63 % (WP)	2gm/ltr
T3	Saizox	Azoxystrobin 18.2 % + Difenoconazole 11.4 % (SC)	3ml/ltr
T4	Kingsin M	Thiophanate-methyl 70%WP	2gm/ltr
T5	Kasu-B	Kasugamycin 3%SL	2ml/ltr
T6	Nativo	Trifloxystrobin 25%+Tebuconazole50% (75WG)	2gm/ltr
T7	Control	-	-

Cultural practices

Chaite-5, variety of rice was used for the purpose of this study. A slightly raised nursery bed was prepared by ploughing followed by laddering. Sprouted seeds were evenly broadcasted along the bed and light irrigation was provided whenever needed. One week before transplanting the seedlings, the main plot of the experiment was ploughed using power tiller and it was left for sundry for a week. After one week, to achieve better puddle condition, the land was continuously harrowed and ploughed followed by laddering. When final land preparation was done, 23 days old seedlings were transplanted on 21st March, 2021 by maintaining a distance of 20*20 cm^2 between the row and plant. After a week of transplanting, each plot was examined for any missing hills, which were filled in as needed with additional seedlings from the same source.

Each plot was evenly provided with FYM as a source of organic fertilizer and inorganic fertilizers such as urea, TSP, MoP, gypsum, zinc sulphate and borax were applied as a source of N, P, K, S, Zn and B respectively. A total of all inorganic sources of fertilizers were applied as a basal dose except nitrogen. Half nitrogen was applied as basal dose and the remaining half was applied evenly in two splits at tillering and panicle initiation stage. Different fungicide like Hexaconazole5%(SC), Carbendazim12%+ Mancozeb 63%(WP), Azoxystrobin 18.2 % + Difenoconazole 11.4% (SC),Thiophonate-Methyl 70%wp, Kasugamycin 2% Wp and Floxystrobin+tubuconazole were applied thrice at 15 days intervals. During the early stage of seedling establishment, to maintain a constant level of standing water up to 6 cm irrigation was provided. Later, irrigation was provided at different vegetative and reproductive stages avoiding water stress. Then 15 days piror to harvesting, field was kept dry. Weeding was done twice at 30 DAT and 60 DAT. Harvesting was done when 80-90% of the grain turned straw-colored on July 26, 2021.

Observations recorded

Disease Severity

Data on disease severity were collected from randomly selected ten plants except the plants along the borderline on a weekly basis beginning from the fourth week after transplantation until six scorings were completed. The 0-9 scale was used for scoring, and the percentage of disease was calculated using the formula (Bhusal et al. 2018).

Disease Severity =

$$\frac{Sum of Score}{Number of observation * Highest number in rating scale} * 100$$

Table 2. Scale for disease scoring of Leaf blast disease of Rice

Scale	Description	Host behavior
0	No lesion observed	Highly resistance
1	Small brown specks of pin-point size or larger brown specks without sporulating center	Resistance
2	Small roundish to slightly elongated, necrotic gray spots, about 1-2 mm in diameter, with a distinct brown margin	Moderately resistance
3	Lesion type is the same as in scale 2, but a significant number of lesions are on the upper leaves	Moderately resistance
4	Typical susceptible blast lesions 3 mm or longer, infecting less than 4% of the leaf area	Moderately susceptible
5	Typical blast lesions infecting 4-10% of the leaf area	Moderately susceptible
6	Typical blast lesions infection 11-25% of the leaf area	Susceptible
7	Typical blast lesions infection 26-50% of the leaf area	Susceptible
8	Typical blast lesions infection 51-75% of the leaf area and many leaves are dead	Highly susceptible
9	More than 75% leaf area affected	Highly susceptible

Statistical analysis

The entry of the data was done on MS-excel (2007) and analysis was done with the help of Gen-stat (15 version). Mean comparison was carried out among significant variables by fisher-LSD at 5%level of significant.

RESULTS AND DISCUSSION

There was highly significant different ($p \leq 0.001$) in mean disease severity (%) of rice blast among treatments (Table 3). The lowest disease severity was observed in Azoxystrobin+Difenconazole (7.28%) treated plot which was at par with Carbendazim+ Mancozeb (7.71%). The highest disease severity was recorded in control (31.36%) plot followed by Hexaconazole (14.65%) and Thiophanate-Methyl (12.90%) which was significantly different with each other.The highest percentage reduction in disease severity over control was brought by Azoxystrobin+Difenconazole (76.79%) followed by Carbendazim+ Mancozeb (75.45%) and Tebuconazole+ Trifloxystrobin (69.71%) and least was brought by Hexaconazole (53.28%)

The disease severity of different fungicides is shown in the graph (Fig 1). All the tested fungicides showed different severity percentages after different weeks of transplanting. Control on different weeks of transplanting showed increasing growth of severity percentage.Azoxystrobin18.2%+Difenconazol11.4%SC showed decreasing disease severity percentage and showed the least disease severity as compared to other fungicides. The highest disease severity was shown by Hexaconazole 5%SC. Six different fungicides showed a decreasing trend in disease severity after 6-7th weeks of transplanting as compared to control.

Table 3. Effect of different treatments on mean disease severity of rice blast at Dhangadhimai-12, Siraha, 2021

Treatments	Mean disease severity ^{x} (%)	PROC (Disease severity)
Azoxystrobin 18.2%+Difenconazole11.4%SC	7.28^{a} (15.65)	76.79
Carbendazim12%+ Mancozeb 63%WP	7.71^{a} (16.10)	75.45
Tebuconazole 50% + Trifloxystrobin 25%WG	9.50^{b} (17.94)	69.71
Kasugamycin 3% WP	9.75^{b} (18.19)	68.91
Thiophanate-Methyl 70%WP	12.90^{c} (21.04)	58.86
Hexaconazole 5%SC	14.65^{d}(22.50)	53.28
Control	31.36^{e}(34.06)	0
Mean	20.78	
SEd	0.565	
LSD(0.05)	1.231	

^{x}Values are mean of four replications at different date of disease scoring; PROC: Percentage reduction over control; CV: Coefficient of variation; ***: Significant at 0.1% level of significance; Values with same letters in a column are not significantly different at 5% level of significance by DMRT. Figures in parentheses indicate arcsine transformation values.

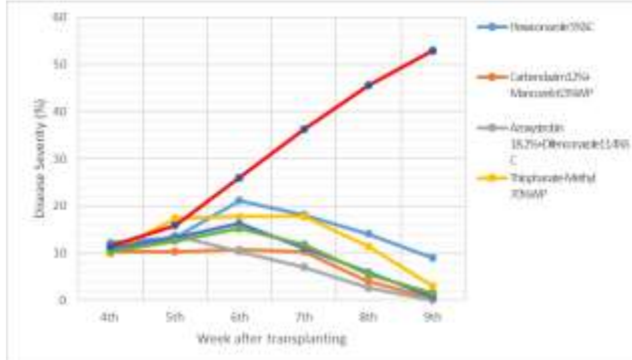

Figure 1. Disease severity at different weeks after transplanting

Yield

There was a highly significant difference ($p \leq 0.001$) in yield (mt/ha) of rice blast among treatments (Table2). The highest yield was observed in Azoxystrobin+Difenconazole 5.16mt/ha treated plot which was at par with Carbendazim12%+ Mancozeb 63%WP (5.12m/ha). The lowest yield was recorded in the control (3.62mt/ha) plot followed by Hexaconazole (4.18mt/ha) and Thiophanate-Methyl 70%WP (4.37mt/ha) which are significantly different with each other.

The highest percentage increase in yield over control was brought by Azoxystrobin +Difenconazole (42.74%) followed by Carbendazim+ Mancozeb (41.55%) and Tebuconazole + Trifloxystrobin (38.87%) and least was brought by Hexaconazole (15.48%).

Table 4. Effect of different treatments on yield of rice at Dhangadhimai-12, Siraha, 2021

Treatments	Yield^{y} (mt/ha)	PIOC(Yield)
Azoxystrobin 18.2%+Difenconazole11.4%SC	5.16^{a}	42.74
Carbendazim12%+ Mancozeb 63%WP	5.12^{ab}	41.55
Tebuconazole 50% + Trifloxystrobin 25%WG	5.02^{bc}	38.87
Kasugamycin 3% WP	4.93^{c}	36.30
Thiophanate-Methyl 70%WP	4.37^{d}	20.74
Hexaconazole 5%SC	4.18^{e}	15.48
Control	3.62^{f}	0
Mean	4.628	
SEd	0.0587	
LSD(0.05)	0.1279	

^{y}Values are mean of four replications; PIOC: Percentage increase over control; CV: Coefficient of variation; ***: Significant at 0.1% level of significance; Values with same letters in a column are not significantly different at 5% level of significance by DMRT.

There was a significant variation of all the treatments in blast disease reduction and grain yield. Compared to control, there was a significant variation of all six fungicidal treatments in reduction of the disease

incidence and severity. This experiment shows that, three sprays of (Azoxystrobin18.2% + Difenconazole11.4% SC) not only reduced the disease severity but also resulted in a higher grain yield, followed by Carbendazim12% + Mancozeb 63%WP.
Similar results were also reported by many researchers earlier. The application of Azoxystrobin 18.2%+ Difenconazole 11.4%SC was found most effective in controlling leaf blast, with a significant reduction in the disease severity and maximum grain yield (Singh et al. 2019). According to Singh et.al (2010) the use of carbendazim 12% + mancozeb 63% significantly reduced the neck blasts. While testing various fungicides, researchers from around the world has discovered similar results. Upadhyay et al(2020) has also mentioned that the combination product trifloxystrobin 25% + tebuconazole 50% WG the combination product trifloxystrobin 25% + tebuconazole 50% WG significantly reduced disease severity and improved rice grain yield, followed by Azoxystrobin 11% + tebuconazole 18.3% w/w SC @ 1.5 ml/l.
Among five fungicide under study conducted by Ahmad, Shahid, Ali, Anjum, et al(2020) Tebuconazole 50% + Trifloxystrobin 25%WG was most effective for controlling blast in rice. This finding is consistent with (Gn, 2018; Acharya et al., 2020; Moktan et al., 2021;Ghazanfar et al. 2009) who discovered the fungicides application increases rice yield. Researchers from around the world also found similar results while testing the various fungicides,(Magar et al. 2015b) at Karma Research and Development Center, Jyotinagar, Chitwan, Nepal used seven fungicides for rice blast management were sprayed thrice at weekly intervals starting from the booting stage.

CONCLUSION

Diseases are a major problem that reduces the crop yield. Over the years, the rice blast severely reduced grain yields, which resulted in a food shortage. It has been discovered that various chemical fungicides can effectively control a variety of plant diseases. The study discovered that fungicide treatments were more effective against leaf blast than the control. As a result, the plot treated with Azoxystrobin+Difenconazole (7.28%) had the lowest disease severity. Azoxystrobin and Difenconazole also provided the greatest percentage reduction in disease severity over control (76.79%). Azoxystrobin+Difenconazole produced the highest yield (5.16 MT/ha). It was concluded that Azoxystrobin (18.2%) and Difenoconazole (11.4%) can be advised for farmers to combat leaf blast because they are so efficient and easily accessible on the market.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

Determination of Acetamipride and Profenofos Residues in Cabbage Using QuECHERS Method in Sohag, Upper Egypt.

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ABSTRACT
Our investigation included cabbage leaves for insecticides residue analysis. We had been treated by the formulation acetamipride (Mosiplan 20% SP) and profenofos (Ictacron 72% EC) and residues were estimated by HPLC. The findings demonstrated that for each insecticide, a different amount of residues were recorded over the trial period. Acetamipride and profenofos had early deposits of 0.88 and 1.85 ppm on and in unwashed cabbage leaves, respectively. Acetamiprid and profenofos residues on unwashed cabbage leaves were 0.50 ppm and 1.07 ppm, respectively, after the first day of spraying. These reduced to 0.11 and 0.39 ppm on washed cabbage with tap water. To reduce the concentration of pesticide residues in cabbage leaves, it is vital to wash the leaves with tap water as residue loss increases with the amount of time that has passed after spraying began until the end of the trial period. It indicates that acetamiprid was degraded faster than profenofos. These variations in the rate of disappearance of various insecticides could be related to variations in chemical formulation and structure as well as application rates. The safety time after which cabbage plants sprayed with acetamipride and profenofos may be picked up was the first and seventh days, respectively, according to maximum residues limits (MRLs).
Keywords: Cabbage, Residues, Acetamipride, Profenofos, QuEChERS

INTRODUCTION

Vegetables are essential to human nutrition and health, because they include minerals, micronutrients, vitamins, and antioxidants. Poisonous substances known as pesticides are used to prevent, eliminate, or control pests throughout the production, processing, transportation, and marketing of food. Food safety has a big impact on human health, which is why people are more worried about eating safe food. Pesticide residues in food are one of the most recent problems to draw public attention on a global scale (Inobeme et al., 2020), especially in vegetables crops. Certain agricultural crops cannot be cleaned of pesticide residues by washing or cooking, indicating that the pesticide may have permeated the crops. The worry of the impact of increasing population on food security has led to a further increase in the use of pesticides in agriculture as a result of the world's population's rapid growth, which is expected to reach 8.5 billion people by 2030 (Liu et al., 2015). Europe, China, and subsequently the US are the three regions that use pesticides the most. Around 25% of the utilization is in African nations, with vegetable farming accounting for the majority of cases (De Bon, 2014). Due to their slow rate of degradation, some pesticides can bio accumulate up to 70,000 times their active components in the environment. Therefore, it is necessary for national authorities and regulators to control and enforce maximum residue limits (MRLs) through routine pesticide inspection (Kaushik et al., 2017). The maximum allowed level of pesticide residues (expressed in mg/kg) in food products and animal feeds that is both legally permissible and toxicologically acceptable is set by the Codex Alimentarius Commission (FAO, 2013). It represents the greatest residual ratio that might be anticipated if the crop was pesticide-treated in accordance with label recommendations and other allowed Good Agricultural Practices (GAP).

In order to reduce health risks, this research sought to examine the persistence of the aforementioned insecticide residues in cabbage plants and provide guidance on the pre-harvest interval (PHI) that should elapse after treatment and prior to commercialization. This study also aimed to shed light on how washing with tap water affected the elimination of pesticide traces from cabbage leaves.

MATERIALS AND METHODS

Insecticides used

Cabbage was cultivated under open field and sprayed by two insecticides, acetamipride (Mosiplan 20% SP) at 25 g / 100 L water and profenofos (Ictacron 72% EC) at

350mL/ 100 L water, respectively, according to Technical Recommendations for Agricultural Pest Control (2017) and determine the residues of these chemicals in cabbage. The experimental area was divided into plots of 42 m2 (1 / 100 Fed.). The layout of the experimental region was a fully randomised block. To act as a control, three plots were not given any treatment. The commercial production of cabbage involved manipulating all agricultural methods.

Insecticides bioassay

The rates listed above were used to apply the pesticides (recommended dose). A skilled operator applied the spray. A Knapsack-sprayer (Cp-3) with one nozzle that delivers (200 L/fed.) was used for the spraying, and it has proven to be sufficient to provide good coverage on the treated plants. The dissipation rate of the chemical on cabbage and the terminal residues in the finished products were investigated using residue trials carried out in accordance with crucial Good Agricultural Practices (GAPs).

Determination of acetamipride and profenofos residues in cabbage leaves

Extraction and clean-up processes

Ten heads of cabbage were collected randomly from each plot in open field and then taken two equal parts (500 g). To evaluate the impact of washing on the loss of the tested pesticides, the first half was washed three minutes with running tap water and then allowed to dry on clean paper for 30 minutes at room temperature. The second part was left untreated. The extraction and clean -up processes were carried out at the Water and Environment Laboratory in the Regional Center for the Development of Southern Upper Egypt - Quraman Island – Sohag. The samples were prepared with the QuEChERS method (Anastassiades, *et al.,* 2003).

A 50 mL PTFE centrifuge tube containing 10 grammes of homogenised cabbage sample was weighed, 10 mL of acetonitrile was added, the tube was vortexed for 1 minute, 4 grammes of anhydrous MgSO4 and 1 grammes of sodium chloride were added, the tube was vortexed for 30 seconds, and the mixture was centrifuged at 4000 rpm for 5 minutes. For cleanup, 1.0 mL of acetonitrile was placed into a 2.0 mL centrifuge tube. The dSPE tubes containing 25 mg PSA and 150 mg MgSO4 received an aliquot of 1 mL. The tubes were securely closed, vortexed for 30 s, and then centrifuged at a speed of about 4000 rpm for 5 min. In order to inject the mixed eluate into the HPLC, a 0.22-m nylon syringe filter was used.

Chromatographic conditions

The final determination of acetamiprid samples was carried out in HPLC. It system is an Agilent 1260 series with a photodiode array detector attached to an analytical column with dimensions of 150 mm 4.6 mm id, 5 m ODS. The mobile phase (acetonitrile 70% + water 30%) flow rate for acetamiprid was 1 ml/min, and the injection volume was 20 µl. A 205 nm detection wavelength was used. Under these conditions the retention time was 3.66 for, acetamiprid (Fig.1). While the HP6890 gas chromatograph outfitted with a flame photometric detector (FPD) was used for the final determination of profenofos Smples, a 30 m x 0.32 mm capillary column coated with a 0.25 m thick film of 14% cyanopropilsiloxane (PAS-1701) and a phosphorus filter were also used. The following was the oven temperature programme: 160 oC at start for 2 minutes. 6 oC every minute up to 260 oC, held for 30 minutes. The flow rate of the carrier gas (N2) was 4 ml/min. At 240 oC, a splitless injection of a 2-l volume was performed. The flow rates for the hydrogen and air used were 75 and 100 ml/min, respectively. 250 oC was the detector's temperature. In these circumstances, the retention time for profenofos was 5.276 minutes (Fig.2).

Recovery studies

Untreated cabbage leaves were strengthened by adding a standard solution of profenofos and acetamipride at concentrations ranging from 0.1 to 1.0 ppm. To validate the assay technique, the fortified samples were processed through each stage of the analytical method. The recovery percentages from fortified untreated samples were used to rectify the results (Table 1).

RESULTS AND DISCUSSION

Recovery percentages of acetamipride and profenofos

Table (1) displays the acetamipride and profenofos recoveries from fortified samples (50 g) at various processing steps. Acetamipride recovery rates ranged from 105.38 to 92.58%, whereas profenofos recovery rates ranged from 90.28 to 80.32%. The average of recoveries for acetamipride was 87.71 %, while for profenofos was 86.64 %. This result is compatible with Sallam and El-Nabarawy (2001), the same method in determination of chlorpyrifos-methyl, chlorpyrifos, and profenofos on moloukhia leaves. They found that recovery percentage of these insecticide were 86.52, 90.43, and 83.4%, respectively.

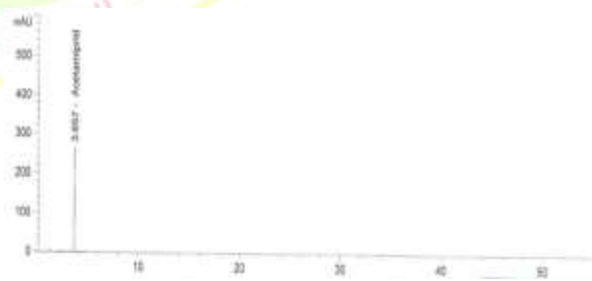

Figure 1. HPLC chromatogram of acetamiprid

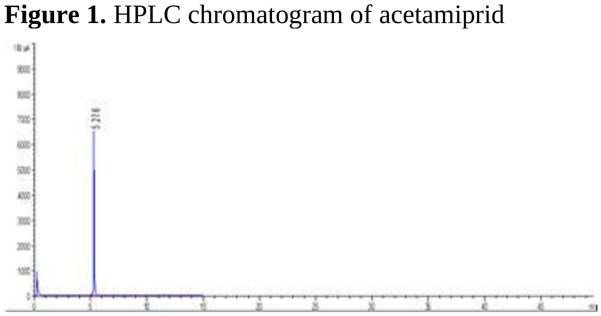

Figure 2. HPLC chromatogram of profenofos

Table 1. Recovery percentages of acetamiprid and profenofos in cabbage leaves.

Spiking level (mg/kg) (n*=3)	Acetamiprid		Profenofos	
	Mean recovery ±SD	% RSD	Mean recovery ±SD	%RSD
0.1	92.58±1.22	1.42	80.32±0.92	4.85
0.5	65.18±1.57	2.55	89.33±2.01	1.05
1	105.38±1.20	2.01	90.28±1.55	0.44
Average	87.71± 1.33	1.99	86.64±1.49	2.11

*: Number of replicates

Residues of acetamiprid and profenofos on and in cabbage leaves cultivated in open field.

The concentration of the initial deposits of profenofos and acetamiprid on unwashed cabbage leaves was 0.88 and 1.85 ppm, respectively, according to the findings in table (2) and figures (3 & 4). Within 24 hours of spraying, the residual levels fell to 0.50 and 1.07 ppm, respectively. The residues of acetamiprid dropped to 0.34, 0.12, 0.01, and undetectable after 3,5,7,12 and 15 days, respectively. The corresponding values for profenofos were 0.55, 0.08, 0.01, and undetectable ppm . With each pesticide, a different amount of residues was recorded over the testing period. These levels varied depending on the initial depositions, the speed at which the cabbage heads were exposed to external variables, and how the treated surface responded to the chemical used. Stevens, et al., (1988) demonstrated that uptake of pesticides on plant surface is affected by, the chemical composition, formulation, rate of insecticide employed, type of recipient surface, spraying equipment used, and climatic conditions particularly the ambient temperature, especi ally during pesticide application.

Data presented in Table (2) demonstrates that as time passed from the start of spraying to the completion of the trial period, residue loss grew. For acetamiprid and profenofos, the loss percentages after one day from the start of spraying were 43.18 and 42.16, respectively. More than 85% of the acetamiprid residues had gone by the fifth day. While with profenofos, the early deposits vanished to a greater than 95% extent. The same phenomenon took place with Shiboob, (1995), he discovered that after 12 days of spraying, profenofos residue loss percentages in tomato and cucumber fruits varied from 99.1 to 99.3%.

Acetamiprid and profenofos residues in unwashed cabbage leaves had half-lives calculated by Moye, et al., (1987), that were, respectively, 1.8 and 1.49 days. These results are in agreement with Abdalla, et al., (1993), who found that the half-life values (RL50) of profenofos residues was 3.2 days on tomato fruits, while Salam and El-Nabrawi (2001) reported that profenofos on moloukhia leaves had a half-life of 52.08 hours.

It is obvious that acetamiprid was degraded faster than profenofos (Fig.3 & 4). These variations in the rate of disappearance of various insecticides could be related to variations in chemical formulation and structure as well as application rates. The same conclusion was mentioned by Sallam and El-Nabarawy (2001), that degradation rate, was correlated to the chemical structure of the tested compounds.

According to the maximum residues limits (MRLs) of acetamiprid (0.7 ppm) Codex (2012), and profenofos (0.01 ppm) EU (2017) in cabbage leaves. Acetamiprid and profenofos –sprayed cabbage leaves can be picked up after 1 and 7 days, respectively from spraying. The same conclusion was pointed out by El-Sayed, et al., (1977), they reported that according to their findings, there should be a one- to twelve-day waiting period between the spraying of insecticides and the harvesting of produce for commercialization in order to protect consumer safety and prevent health hazards.

Effect of washing process in removing on acetamiprid and profenofos residues from cabbage leaves.

Data in Table (2) indicated the great influence of washing with tap water in removing or elimination of acetamiprid and profenofos residues from sprayed cabbage leaves. Acetamiprid and profenofos residues on unwashed cabbage leaves were 0.50 and 1.07 ppm, respectively, after one day of spraying. On cabbage that had been washed with tap water, these were reduced to 0.11 and 0.39 ppm. The results showed that the amounts of acetamiprid and profenofos residues in washed cabbage were much lower than those in the unwashed cabbage. Washing process removed residues from 55.68 to 91.18 and 37.50 to 63.55 % respectively, for acetamiprid and profenofos on cabbage leaves. Such findings are in agreement with that obtained by Zhi-Yong Zhang, et al., (2007), they measure the quantities of pesticide residue (chlorpyrifos, p,p-DDT, cypermethrin, and chlorothalonil) in cabbage during the home preparation process by washing with various acetic acid and salt chloride concentrations as well as tap water. The findings demonstrated that the aforesaid pesticides lost to washing with acetic acid solutions (at 10% concentration for 20 min), NaCl solutions (at 10% concentration for 20 min), and tap water (for 20 min). To reduce or remove pesticide residues in agricultural products, many techniques and tools have been developed. These techniques include washing, chilling, peeling, boiling, and ozonation Li, P.-K, et al., (2004).

CONCLUSION

These results concluded that acetamiprid residue was reduced more quickly than profenofos on cabbage leaves that had been rinsed with tap water and left traces of both pesticides. Variances in chemical composition and structure as well as treatment rates may be responsible for these variances in the rate at which different insecticides vanish. The first and seventh days, respectively, were the safe periods after which cabbage plants treated with acetamipride and profenofos may be harvested.

Table 2. Residues of acetamiprid and profenofos on and in cabbage leaves cultivated in open field.

Days after spraying	Acetamiride				Profenofos			
	Unwashed		Washed		Unwashed		Washed	
	Residues (mg/kg)	% Loss	Residues (mg/kg)	% Loss	Residues (mg/kg)	% Loss	Residues (mg/kg)	% Loss
0	0.88	0.00	0.39	55.68	1.85	0.00	0.84	54.59
1	0.50	43.18	0.11	78.00	1.07	42.16	0.39	63.55
3	0.34	61.36	0.03	91.18	0.55	70.27	0.21	61.82
5	0.12	86.36	ND	---	0.08	95.67	0.05	37.50
7	0.01	98.86	ND	---	0.01	99.45	ND	---
12	ND	---	ND	---	ND	---	ND	---
15	ND	---	ND	---	ND	---	ND	---
18	ND	---	ND	---	ND	---	ND	---
MRL	0.7 Codex (2012)				0.01 EU (2017)			
PHI	1 day				7 days			
RL50	1.8		0.98		---			

ND = (Not detectable); MRL = (Maximum Residue Limits); PHI =(pre harvest intervals); RL50 =(Residue half-life)

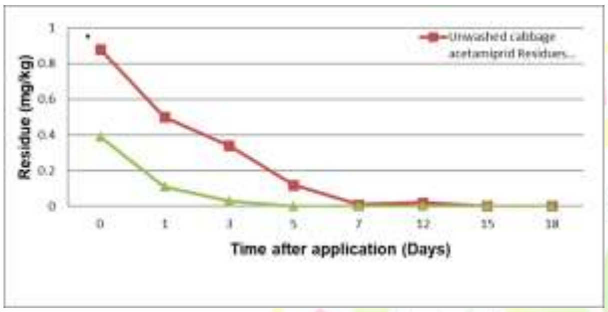

Figure 3. Persistence of acetamiprid residues on and in cabbage leaves

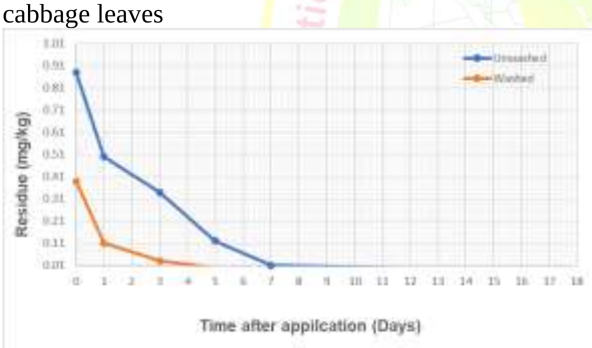

Figure 4. Persistence of profenofos residues on and in cabbage leaves

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Research Article

Effect of agricultural products price fluctuations on smallholder farmer's welfare in Rwanda. A case study of Gicumbi, Nyagatare, Nyaruguru, Rubavu Districts.

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ABSTRACT

Agriculture sector is the main motel of life in the world. The price of agricultural products plays an important role in regulating production and consumption mechanism. Mainly farmers have been affected by different problems in supply of the products particularly price fluctuation. This paper aims to assess the effect of agricultural products price fluctuations on smallholder farmer's welfare. A case study of Gicumbi, Nyagatare, Rubavu, and Nyaruguru districts. A cross sectional research design was used in the study where both purposive and simple random sampling techniques were used to select a sample size of 120 respondents. A regression analysis technique was used to identify the factors influencing price fluctuation through SPSS and STATA software. The results from the regression analysis indicated that various factors influencing price fluctuation of agricultural production including type of market, seasonal production, climate condition change, middlemen, farm inputs price, nature of product, price of petroleum, and political stability. The results of the study also indicated the effect of good price on farmers 'lifestyle change through the increased farmer' income, improved farmers livelihood, reduced the youth migration, increased their money savings, and the effective utilization of farm inputs. The study also revealed different measures for price fluctuation control; these include provision of subsidies to farmers, government price control, improvement of infrastructures, control of middlemen in agriculture sector, market stability, improvement of farming system, and creation of buffer stock zones in agro-ecological regions. As the rural and urban life mainly dependent on farmers 'produce the stability of price of agricultural products should be control along the whole value chain in all possible area particularly at farm get and market level both regional and district.
Keywords: Price fluctuation, Agricultural products, smallholder farmers, Welfare

INTRODUCTION

Agriculture plays a fundamentally important role in the economic growth and development prospects of a vast majority of developing countries including Rwanda. Agriculture sector is a major and is a main source of livelihood, providing direct employment. The sector occupies 79.5 percent of the labour force, contributes one-third of GDP and generates more than 45.0 percent of the country's export revenues. Agriculture is also important for national food self-sufficiency, accounting for well over 90.0 percent of all food consumed in the country (GoR, 2011). The majority of agriculture is undertaken by smallholder farmers and price volatility affects their livelihoods and access to market goods and services (Mitchell, D, 2010).

The most important problem in sub-Saharan agriculture is the well-being of farmers, where farmers 'most important protection comes from food production. Most African's agricultural prices have shown a trend of frequent fluctuations, which has had a very negative effect on farmers' agricultural production and agricultural economy. The issue of food losses is of high importance in the efforts to combat hunger, raise income and improve food security in the world's poorest countries. Food losses have an impact on food security for poor people, on food quality and safety, on economic

development and on the environment (FAO, 2011). The exact causes of food losses vary throughout the world and are very much dependent on the specific conditions and local situation in a given country.

African countries became more dependent on commodity production and exports than in the past. Supported also by very low global interest rates, large investments took place in the exploration and production of commodities as well as in supporting industries such as energy generation, construction and transportation (World Bank, 2015). Commodity price declines affect all sectors of the economy (corporate, household, government and banking) through very many channels. Falling commodity prices have also reduced capital inflows for investment and increased the risk premium on external sovereign borrowing. To the extent that reduced investment inflows were associated with a decline in imports, there was no change in the overall balance of payments. Surges in food prices and increases in the prices of inputs such as fertilizers reduce the incomes of poor and vulnerable households and put stress on family budgets (FAO, 2008).

African Countries including Rwanda with deficit in production of agricultural commodities have been identified to face serious economic challenges because the cost of imports of agricultural commodities is very high and may lead to deficit in balance of payments (FAO *et al.*, 2011). Frequent fluctuations in agricultural products prices are not conducive to farmers forming stable food price expectations; thus, farmers cannot use food prices to make a reasonable agricultural production plan for the next year. In addition, a rise in food prices causes other commodity prices to rise, which leads to inflation and is not conducive to Rwanda's economic stability (Happiness Huka *et al.*, 2014).

Price fluctuation is not only harmful to consumers but also affects producers. A study by Oxfam and IDS13 suggests that farmers in developing countries are producing fewer surpluses because of increased input prices. 'High input costs have squeezed people's purchasing power, which means that profits from growing and selling food remain low for those with least scope to diversify and spread risk (Baffes, 2011). A business that is planned to attain growth and maximize revenue will not charge minimum price for its products or services. Price fluctuation is a multifaceted problem attributed to various factors which, when combined, culminate in dangerous consequences for the most vulnerable (Happiness Huka *et al.*, 2014). The pricing of agricultural products is an important part of Rwanda's macro-control policies for economic development, and the implementation of such policies has a very important role in the supply and demand of agricultural products in Rwanda. Food pricing also has a crucial impact on Rwanda's economic development and the welfare of farmers. Frequent fluctuations in food prices will make it difficult for the government to implement effective macro-control measures for the agricultural products market.

High international prices for food commodities benefit countries that export those products, while low prices benefit importing countries. Agricultural research and cost-effective irrigation are urgently needed in order to reduce the production risk facing farmers, especially smallholders. These types of investments will reduce price volatility and will lower production costs per tonne, which will reduce food prices (Descargues.S,2011). Commodity prices are volatile and extremely difficult to predict. It is also difficult to transfer their price risk to global financial markets. Moreover, experience from all continents shows that governments have had difficulties in putting in place a macroeconomic framework that safeguards the stability of economic growth during commodity price swings (I M F, 2015c).

Thus, the fluctuation of the price of agricultural products is closely related to Rwanda's agricultural production and food security. High input costs have forced people's purchasing power, which means that profits from growing and selling food remain low for those with least scope to diversify and spread risk.

In order to be effective at reducing the negative consequences of price volatility, targeted safety-net mechanisms must be designed in advance and in consultation with the most vulnerable people. The principal instruments that could be used to manage the price volatility of food imports are futures and options contracts (Dorosh. P, 2009). Over the longer term, however, the reduced risk faced by farmers can encourage them to invest in more-profitable technologies that raise their productivity and income.

Governments must reduce food waste in developed countries through education and policies, and reduce food losses in developing countries by boosting investment in the entire value chain, especially post-harvest processing. More sustainable management of our natural resources, forests and fisheries are critical for the food security of many of the poorest members of society. To be optimistic that global food security will be achieved. To make a progress and better control of the future will make us to be committed to favorable policies, market information transparency, sound analysis, good science and adequate funding for appropriate interventions (FAO, 2011). Due to the observed effect of price fluctuation of agricultural products on smallholder farmers income, this paper aims to identify the factors influencing price fluctuation of agricultural products, to assess the effect of stable price on smallholder farmers welfare, and to determine the measures to control price fluctuation.

MATERIALS AND METHODS

A cross sectional research design was used in the study where two sectors were selected for from each of four chosen namely Gicumbi of Northern Province, Nyagatare of Eastern Province, Rubavu of Western Province, and Nyaruguru of South Province as the study area. Both purposive and simple random sampling techniques were used to select a sample size of 120

respondents including farmers from selected sectors. Multiple approaches including questionnaire, interviews were used to gather both primary and secondary data, which enabled the researcher to do cross-data validity checks. Cobb-Douglas model, and regression techniques were used to identify the factors influencing price fluctuation of agricultural production while quantitative techniques involved utilization of descriptive statistics were used to assess the effect of price fluctuation on agricultural production, and measures to address price fluctuation. Descriptive analysis was done using SPSS and regression using STATA software vision 13.

Table 1. Study area and sample size

District	Sector/market	Sample size
GICUMBI	RUBAYA	15
	BYUMBA	15
NYAGATARE	RWIMIYAGA	15
	MIMULI	15
RUBAVU	GISENYI	15
	NYAKIRIBA	15
NYARUGURU	CYAHINDA	15
	KIBEHO	15
Total		**120**

RESULTS AND DISCUSSION

Socio-Economic Characteristics of respondents

The results from 120 respondents sampled in study area. Among the interviewed farmers, 72 (60%) were male and 48(40%) were female. This indicated that male in study area heads more households than female and it indicated that male prefer growing crops that are commercial than those used in family feeding. For this reason, male, receive more information about market price than female. The results also revealed that in study area the majority of respondents are presented by 45(37.5%) with age ranged between 41-50 years followed by the range of 31-40 years with 36(30%). This means that majority of the respondents were within the working age class. The third class is in the range of 51yeras and above with 24(20%). The last class is that of 30 years and less with 15(12.5%). This is because this class is composed of respondents who do not own land for agriculture and sometimes this class do not prefer agriculture sector due to their and they prefer to migrate to cities like Kigali where they can find other occupations. Based on results the majority in study area indicated that 56(46. 7%) of respondents had primary school education followed by secondary with33 (27.5 %). The university represent 12(10%) while illiterate represent 19(15.8%). The majority of formal educated respondents implies that respondents will be more receptive to farm innovations as well as market information and price situation.

Factors Influencing Agricultural Products Price Fluctuations

The results of the model shows that the data fitted well (R-square = 0.742 and p-value < 0.0001). The results are presented in Table (3). As indicated in table above three variables (type of market, seasonal production, climate condition change) were statistically significant influenced price fluctuation at P<0.001% level. Four explanatory variables (Price of petroleum, middlemen, and market instability, and climate condition change) negatively influenced price fluctuation in study area. While only farming system was not influenced the by price fluctuation.

Table 2. Socio-Economic Characteristics of Sampled respondents

	Frequency	Percentage
Gender		
Male	72	60
Female	48	40
Total	**120**	**100**
Age		
≤ 30	15	12.5
31-40	36	30
41-50	45	37.5
≥ 51	24	20
Total	**120**	**100**
Education level		
Illiterate	19	15.8
Primary	56	46.7
Secondary school	33	27.5
University	12	10
Total	**120**	**100**

For example, change of climatic condition should contribute much on determining the level of harvest to farmers. This is because agricultural supply is mostly based on rain and highly dependent on the weather, therefore for the farmers the annual weather differences is more important than eventual climate change. The study of Gilbert &Morgan (2010) argued that the impact of climate factors on major grain-producing areas could lead to unpredictable food production. In addition, it was found that farm inputs price should cause price fluctuation to farmers, this is because on the product affect the price charges from the agricultural products to be low or high accordingly. This indicated that the importation and exportation of agricultural product also it affects the price sustainability of domestic price of agricultural product. Price of petroleum also affect the agricultural products price fluctuation. This was supported by the study of Sage, A. (2010) indicated that the increase in fuel prices would mean the cost of transporting the produce would also increase. This imply that the prices of food in the local market would rise in order to cut loses that the investors and producers incurred in production and transport. On the other hand, oil prices do not have a direct effect on food prices lately, since more countries are now switching to alternative sources of energy (Davidson *et al*.,2011).

The Seasonal productions is also another factor, most agricultural products are seasonally produced which cause un equal balance of the availability of it and for this reason price tend to be low during long time and to

be high during short time hence to make rise and fall of price in different periods. This also is explained the basic assumption of the cobweb theory is that the current production of the commodity is determined by the price in the previous period. If prices fall, many farmers will go out of business, the next year supply will fall. This causes price to increase. However, this higher price acts as incentive for greater supply. Therefore, next year supply increases and prices plummet again (Sage, 2010). A variation in rice price will give a corresponding change on production, which corresponds with the findings of (Adeniyi, 2009). The result corresponds with the Cobweb theory, which says lower price acts as incentive for lower supply in the next year and higher prices acts as incentive for greater supplies in the following year (Sage, 2010).

Type of market is one among the causes of price fluctuations; there is high difference in level of price stability between monopoly and competitive market within or outside country that make the ever changing of prices for agricultural products from time to time around the year especially when farmer is price taker. If the buyer is the price make there is a higher change of price that can even cause farmer to leave the sector and migration of youth. Price of petroleum fluctuation causes the price of agricultural products to fluctuate; it was argued that the unstable fuel prices cause everything else including farm products to fluctuate more often due to high cost of transporting the farm product from the farm area to the markets.

Nature of products was also indicated to be another cause of price fluctuations; it was established that most agricultural products tend to be perishable in nature as to why it influences the rise or fall of price over time. The perishability nature of some agricultural product especially horticultural crops makes it difficult to store during plenty time hence farmers have to sell them even when the price is still low.

Market instability was also indicated to be another cause of price fluctuations, it was established that most agricultural products tend to be perishable in nature as to why it influences the rise or fall of price over time, when there is a market instability some barriers are created and makes it difficult to get market outside. However, this is directly a cause of price fluctuation. In addition, contingent political instability of the African region has led to mass destruction of agricultural farms and products. As a result, local farmers experience great losses in the production that discourages them from engaging in commercial farming (Eicher, C., and Staatz, 2003). Arezki, R., Brückner, M. (2011) have offered a different view as to how political situation and food prices relate. They explained that higher food prices drive most people of low-income countries to riot and demonstrate against the government, thus, increasing the fragility of the state.

Middlemen variable was also found to be the cause of price fluctuation. This is because they block the value chain of agricultural product and they set the price as they want. This affect production of agricultural products in terms of high cost of production and create a long period between harvesting and selling. When value chain is controlled by, intermediaries price tends be very low for farmers who is selling and very higher to consumer compared to the value chain that was not blocked by these intermediates.

Table 3. Factors Influencing Agricultural Products Price Fluctuations

Variables	**Coef.**	**Std. Err.**	**T**	**P>t**
Farm inputs price	0.033	0.694	0.047	0.089
Type of market	0.028	0.073	0.383	0.000
Seasonal production	0.549	0.517	1.061	0.001
Farming system	0.071	0.477	0.148	0.043
Nature of product	0.023	0.107	0.214	0.052
Climate condition change	-0.414	0.691	0.599	0.000
Price of petroleum	-0.097	0.318	0.305	0.034
Middlemen	-0.068	0.025	2.720	0.000
Market instability	-0.476	0.675	0.705	0.021
Intercept	0.092	0.269	0.342	0.009
Number of obs =120	F(9, 110) = 49.71			
Prob > F = 0.0000	R-squared = 0.742			

Effect of Stable Price on Farmer welfare

The results of the study pointed out that the good price of agricultural product contributed much more to the welfare of farmers. Based on the results in figure above (96.7%) of respondents asked said that satisfactory price increased farmer' income. In this case the per capital incomes of farmer increased in the extent that they can easily afford the basic needs like health insurance, school fess, new house construction or rehabilitation, electricity, food, clothes, and so on. It was indicated that (88.3%) of respondents asked said that good price improved farmers livelihood. They argued that when the price is fair to small scale famers it facilitates them to better change the lifestyle. It was revealed that good price reduced the youth migration where (77.5%) of youth and gender enter the agriculture sector rather than to live the place of birth. For example, youth grow vegetables, fruits and flowers for national and international markets. This is because; youth are more adopters of innovation than older people are as well. Since horticulture crops like fresh beans, broccoli, and amaranths, normally grow very quickly and should be produced more than three times per year it helps youth to meet quickly their basic needs and motivate them to reduce migration. The study indicated that (72.5%) of respondents, asked, said that good price increased their savings and they agreed that good price for agricultural product help farmers and other environment people in their good livelihood. Effective utilization of farm inputs is another contribution of good price to farmers where by (64.2%) the famers use effectively farm inputs and get sufficient production and productivity, which in return facilitate farmers to get more profit for the sector. It was found that the majority of respondent (100%) said that the first major solution to address the problem of

agricultural product price fluctuations is crop insurance followed by agricultural price control (94.3%) through price makers by considering the whole value chain especially from the price of inputs. Provision of subsidies should be one of the best ways in stabilizing prices and gaining control over the market and the economy of the country at larger. The second solution is control of middlemen in agriculture sector, this is because middlemen in value chain they directly became the price makers and price change accordingly. (80.9%) respondents identified intermediaries. The fourth solution is the control of market instability in all agro ecological zones and at all regional and district markets which is represented by (77.7%). The fifth major solution with (62.8%) to address this problem is the improvement and increase of infrastructures as well to overcome the problem of loses both in storage and in transport. The fourth solution to address price fluctuation is the improvement of farming system with (58.5%).

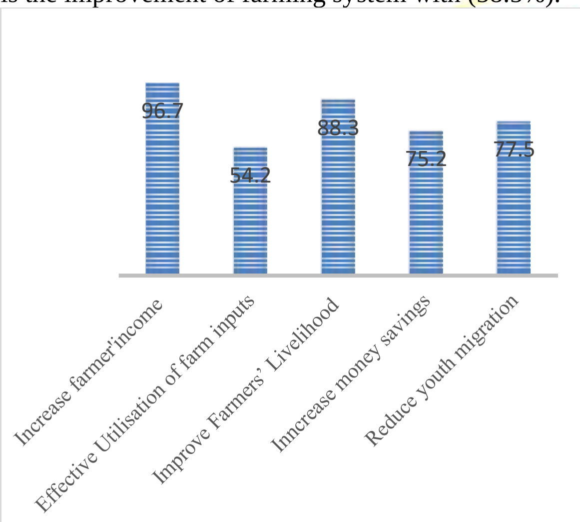

Figure 1. Effect of stable Price on Farmer welfare

This is because if farmers continue to practice subsistence agriculture the policy makers will not be able to control price fluctuation due imbalance between supply and demand. Only decision-makers should intervene in stabilization of price through the establishment of price ceiling and price floor. This is explained by the cobweb theory suggests that prices can become stuck in a cycle of ever-increasing volatility. For example, if prices fall, many farmers will go out of business, the next year supply will fall. This causes price to increase. However, this higher price acts as incentive for greater supply. Therefore, next year supply increases and prices plummet again (Pashigian, 2008). Stabilization of prices of essential agricultural commodities continues to be an area of major concern for policy makers. The last solution given is the creation of buffer stock zones in agro ecological region. It was presented by (44.1%). Having proper buffer stock zones farmers will be able to preserve their surplus and hence balance price through season.

Measures to control agricultural products price fluctuations

It was found that the majority of respondent (100%) said that the first major solution to address the problem of agricultural product price fluctuations is crop insurance and agricultural price control through makers by considering the whole value chain especially from the price of inputs. Provision of subsidies should be one of the best ways in stabilizing prices and gaining control over the market and the economy of the country at larger. The second solution is control of middlemen in agriculture sector, this is because middlemen in value chain they directly became the price makers and price change accordingly. (80.9%) respondents identified intermediaries. The fourth solution is the control of market instability in all agro ecological zones and at all regional and district markets which is represented by (77.7%). The fifth major solution with (62.8%) to address this problem is the improvement and increase of infrastructures as well to overcome the problem of loses both in storage and in transport. The fourth solution to address price fluctuation is the improvement of farming system with (58.5%). This is because if farmers continue to practice the agriculture in subsistence agriculture the policy makers should not be able to control price fluctuation either production should be supplied at the same time or should be absent at the same time that cause price fluctuation. Smallholder farmers undertake the majority of agriculture and price volatility affects their livelihoods and access to market goods and services. Seasonal changes in management practices also affect the productivity of the farming households and can have adverse effect on their welfare. Changes in both market prices and productivity have a potential effect on both food security and nutrition in a country where about 51% of the calories are obtained from the products bought from the market (Benson *et al*, 2008).

Only decision-makers should intervene in stabilization of price through the establishment of price ceiling and price floor. Therefore, it is necessary to encourage population's participation in the agricultural production through the reduction of taxes on locally produced products, which will allow price lowering and demand increase (Mitchell, 2010). Government of both importing and exporting can, can within given limits, use trade policies to protect their domestic market. However, using use trade policies to stabilize domestic market could mean aggravating volatility on international market (Tangermann, 2011). In an attempt to stabilize prices volatility, Government agency may buy grain when prices are low and prices when are high. Stocks can have a more direct and immediate impact in reducing excessive volatility to occur in agricultural commodity market.

This is explained by the cobweb theory suggests that prices can become stuck in a cycle of ever-increasing volatility. For example, if prices fall, many farmers will go out of business, the next year supply will fall. This

causes price to increase. However, this higher price acts as incentive for greater supply. Therefore, next year supply increases and prices plummet again (Pashigian, 2008). Stabilization of prices of essential agricultural commodities continues to be an area of major concern for policy makers.

The last solution given is the creation of buffer stock zones in agr o ecological region. It was presented by (44.1%). Having proper buffer stock zones farmers will be able to preserve their surplus and hence balance price through season. Better marketing infrastructures not only reduce transport costs but also minimizes short-term food price volatility and facilities market transmission. Improving rural marker roads and market facilities such as warehouses is also important in linking smallholders to market; thus increase market supply and contribute to more stable prices (FAO *et al.*, 2011). Increasing public investment in port and transport infrastructures has the potential to reduce price volatility but it would take a long time for this to make major impact in developing countries.

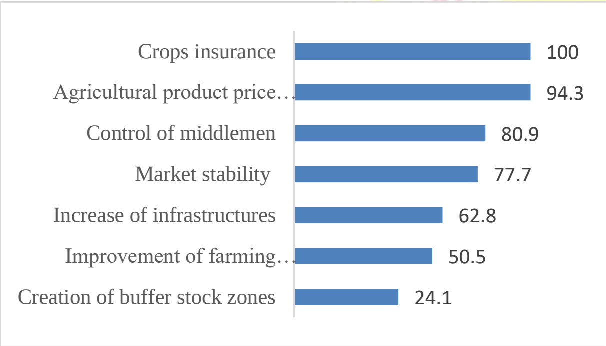

Figure 2. Measures to control agricultural products price fluctuations

CONCLUSION

The results of the study indicated that the well-being, increase of income of smallholder farmers depend on the stability of price of their produce. The results from the regression analysis indicated various factors influencing price fluctuation of agricultural production including type of market, seasonal production, climate condition change, middlemen, farm inputs price, nature of product, price of petroleum, and political instability. The results of the study also indicated that the effect of good price on farmers 'lifestyle change through the increased farmer' income, improved farmers livelihood, reduced the youth migration, increased savings, and the effective utilization of farm inputs. The study also revealed different measures for price fluctuation control; these include provision of subsidies to farmers, government price control, improvement of infrastructures, control and regulation of middlemen in agriculture sector, improvement of farming system, and creation of buffer stock zone in agro-ecological regions.

RECOMMENDATIONS

After the study some recommendations were given:

Price of agricultural products is very low compared to the cost of production, which causes loss of produce. Therefore, crops insurance, contract farming with public and private sectors, production support, Buffer stock and security fund should be enhanced in agriculture sector as well as to stabilize price.

A consultative decision-making approach that brings together supply chain stakeholders and government actors is necessary, as well as to enhance agricultural products marketing and price negotiations between producers and buyers.

Government policy makers needs to improve the capacity of farmers especially in postharvest handling, market survey in order to facilitate farmers to manage the produce and stock food in case of crisis or price fluctuation especially during harvesting period.

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Research Article

Relationship between socio economic profiles of dairy farmers with extent of adoption of improved dairy farming practices in Kumaon division of Uttarakhand.

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ABSTRACT
Livestock sector contributes 4.11 per cent GDP. According to United States Department Agriculture 2018, 80 million households were engaged in dairy farming and majority of them are small scale, marginal farmers. The dairy farming has been considered as a potential means of employment and socio-economic development for people in rural areas. Uttarakhand trails behind from highest milk producing states due to less growth rate in milk production focused should be given to the improved dairy farming to increase milk production and development of dairy industry. The present study was conducted in Kumaon division of Uttarakhand state to find out the relationship between socio economic profile of dairy farmers with their extent of adoption of improved dairy farming practices. Udham Singh Nagar district was selected as for the study. Total 100 respondents from these villages were selected. It was resulted that respondents with higher education, higher land holdings, higher dairy farming experience, higher annual income, higher milk production higher social participation, higher risk preference and higher economic motivation tends to have more extent of adoption of improved dairy farming practices as they are found to have a significant and positive relationship with extent of adoption of dairy farming practices.
Keywords: Dairy farmers, Profit, Kumaon

INTRODUCTION
India is predominantly an agrarian country with animal husbandry playing role in accelerating the growth of rural economy. Thus, it is the backbone of agriculturally based farming sector. Dairying is well known to agricultural system and forms an integral part of rural economy (Shinde *et al*., 1996). Milk production in India is predominantly the domain of small farmers in mixed farming system. India has highest cattle and buffalo population and highest milk production of 105.42 million tonnes but still per animal productivity is very less in the country (19th livestock Census, 2012). In India, low animal productivity results due to climatic, social, economic factors; their per capita production is one of the lowest in the world due to the reasons that the farmers do not adopt the improved dairy management practices at the desired level (Sharma, 2004). Uttarakhand being the state with high number of dairy farmers still lag far behind the highest milk production states of the country. Hence, more focused should be given to the improved dairy farming practices and intervention of government policies and schemes to increase milk production and dairy development of the state. Impoved dairy farming practices plays an integral role in development of socio-economic profile of dairy farmers. Singha *et al*. (2020) revealed that education, farming experience and training received were found positively significant with their extent of adoption of improved dairy farming practices. Krishna and Chakravarthi (2020) revealed that age, education, family size, dairy experience organization participation, land holding was found positively related to adoption of dairy farming practices. The study focused to find out the relationship between socio economic profile of dairy farmers with their extent of adoption of improved dairy farming practices

MATERIALS AND METHODS
The study was conducted in Kumaon division of Uttarakhand. The study was purposively done in Udham Singh Nagar district of Kumaon division as it has highest milk production in this division. In Udham Singh Nagar district, Rudrapur and Sitarganj block were selected by random sampling. Two villages from each block were selected by simple random sampling. Bara and Khamaria village were selected from Rudrapur block and Siseya and Halduwa villages were selected from Sitarganj block. Total 100 respondents were taken purposively for the study. To find out the relationship between socio economic profile of dairy farmers with their extent of adoption of improved dairy farming practices correlation coefficient (r) and t- test were used.

RESULTS AND DISCUSSION

Age

The value of coefficient of correlation was 0.044 (r=0.044) and t calculated (0.435). The t calculated value was less than t tabulated value at 5.00 per cent level of significance and therefore the hypothesis Ho1 was accepted. This shows that there is positive and non-significant relationship between the age and extent of adoption. The results find parallel to the findings of Nande *et al.* (2019).

Education

The value of coefficient of correlation was 0.188 (r=0.188) and t calculated is 1.986. The t calculated value is more than t tabulated at 5.00 per cent level of significance and therefore the hypothesis Ho2 was rejected. This shows that there is positive and significant relationship between the education and extent of adoption. The results are in line with the findings of Singha *et al.* (2020)

Thus, it can be concluded that with more level of education there will be more extent of adoption of improved dairy farming practices. The significant relationship might be due to the reason that the respondents having higher educational level were able to learn and accept the improved practices easily.

Family size

The value of coefficient of correlation was -0.014 (r =0.014) and t calculated is -0.145. The t calculated value is less than t tabulated at 5.00 per cent level of significance and therefore the hypothesis Ho3 is accepted. This shows that there is negative and non-significant relationship between family size and extent of adoption. The results find contingency to the findings of Krishna and Chakravarthi *et al.* (2020).

Annual income

The value of coefficient of correlation is 0.291 (r=0.291) and t calculated is 3.030. The t calculated value is more than t tabulated at 5.00 per cent level of significance and therefore the hypothesis Ho4 is rejected. This shows that there is positive and significant relationship between annual income and extent of adoption. This might be due to the reason that with increase in annual income, dairy farmers can invest and afford more expenses related to improve dairy practices. The results find parallel to the findings of Bhise *et al.* (2018).

Land holding

The value of coefficient of correlation is 0.245 (r=0.245) and t calculated is 2.947. The t calculated value is more than t tabulated at 5.00 per cent level of significance and therefore the hypothesis Ho5 is rejected. This shows that there is positive and significant relationship between annual income and extent of adoption. The results are line with the findings of Satyanarayan *et al.* (2017)

Herd size

The value of coefficient correlation is 0.043 (r=0.043) and t calculated is 0.432. The t calculated value is less than t tabulated at 5.00 per cent level of significance and therefore the hypothesis Ho6 is accepted. This shows that there is positive and non-significant relationship between herd size and extent of adoption. It can be concluded that with increase in herd size farmer gets to adopt more practices that should be follow for better survival of their dairy animals and more milk production. The results find parallel to the findings of Harilal *et al*. (2018).

Dairy farming experience

The value of coefficient correlation is 0.191 (r=0.191) and t calculated value is 1.960. The t calculated is more than t tabulated at 5.00 per cent level of significance and therefore the hypothesis Ho7 there is a positive and significant relationship between dairy farming experience and extent of adoption. This is because of the fact that more experience would make them aware of the newly introduced practices that should be practice for proper management of the animals. The results find contigency with the findings of Ratnaparkhi *et al.* (2017).

Milk production

The value of coefficient of correlation is 0.185 (r=0.185) and t calculated is 1.873. The t calculated is more than t tabulated at 5.00 per cent level of significance and therefore Ho10 is rejected. This shows that there is a positive and significant relationship between milk production and extent of adoption. The results find parallel to the findings of Sachan *et al.* (2013).

Social participation

The value of coefficient of correlation is 0.330 (r=0.33) and t calculated is 3.464. The t calculated is more than t tabulated at 5.00 per cent level of significance and therefore the hypothesis Ho9 is rejected. This shows that there is a positive and significant relationship between social participation and extent of adoption. The reason behind such results might be that the dairy farmers will discuss and get knowledge about various new practices while participating more in their social groups. The results find parallel to the findings of Singhal and Vatta (2019).

Economic motivation

The value of coefficient of correlation is 0.314(r=0.314) and t calculated is 3.275. The t calculated is more than t tabulated at 5.00 per cent level of significance and therefore the hypothesis Ho11 is rejected. This shows that there is a positive and significant relationship between economic motivation and extent of adoption. It can be concluded that with higher economic motivation there will be more extent of adoption of improved dairy farming practices. The results are in line with the findings of Sarah *et al.* (2021).

Risk Preference

The value of coefficient of correlation is 0.222 (r=0.222) and t calculated is 2.885. The t calculated is more than t tabulated at 5.00 per cent level of significance and therefore the hypothesis Ho12 is rejected. This shows that there is a positive and significant relationship between risk preference and extent of adoption. It can be concluded from the results that higher the dairy farmers want to take risks in their occupation higher they would

adopt the advanced and improved practices. The results find parallel to the findings of Singha *et al*. (2020).

Table 1. Relationship between socio economic profile with their extent of adoption of improved dairy farming practices.

Independent variable	Correlation coefficient	t-calculated
Age	0.044	0.435
Education	0.188*	1.986
Land holding	0.245*	2.947
Family size	-0.014	0.145
Herd size	0.043	0.432
Dairy farming experience	0.191*	1.960
Milk production	0.185*	1.873
Annual income	0.291*	3.030
Social participation	0.330*	3.464
Risk preference	0.222*	2.885
Economic motivation	0.314*	3.275

**Significance at 0.05 level of probability; t value at 0.05 level of significance (df=99) =1.660*

CONCLUSION

On the basis of above discussion, this can be concluded that respondents with higher education, higher land holdings, higher dairy farming experience, higher annual income, higher milk production higher social participation, higher risk preference and higher economic motivation tends to have more extent of adoption of improved dairy farming practices as they are found to have a significant and positive relationship with extent of adoption of dairy farming practices.

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Research Article

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Morpho-physiological and phenological response of rice (*Oryza sativa* L.) genotypes to low temperature stress at reproductive stage

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ABSTRACT

The yearly changes in atmospheric temperature are projected to negatively affect food production in several locations. Rice exposure to low-temperature stress can decrease plant growth in different stages, notably during the reproductive period. A field experiment was conducted in ARS Gangavathi, Karnataka. The experiment laid out in factorial randomized block design where four different rice genotypes (GNV-10-89, GNV-1801, GNV-1108 and BPT-5204) transplanted under two different dates of transplanting D_1 (normal *Kharif*-15th September) and D_2 (late *Kharif*-30th September). The low temperature during the reproductive stage was 14.1°C which inhibited the morphological, physiological, phenological and yield traits of rice crop. All the observations were recorded at the flowering stage (95 DAT). The results revealed that morphological traits like plant height, number of green leaves, number of productive tillers, total dry matter, total leaf area and root length were high in D_1 than D_2 (101.6 & 99.76 cm, 21.5 & 16.1 hill^{-1}, 14.5 & 11.5 hill^{-1}, 29.0 &21.1 g hill^{-1}, 3.79 & 4.11 dm^2 hill^{-1} and 14.6 & 18.2 cm), physiological traits such as photosynthetic rate (14.55 & 13.45 µ mole CO_2 m^{-2} s^{-1}) and Transpiration rate (12.86 & 11.01 m mole H_2O m^{-2} s^{-1}) similarly phenological traits, DPI (80.6 & 90.5 days), DF (98.3 & 102.3 days), DPM (116.7 & 127.2 days) and DHM (124.7 & 135.4 days). Reproductive traits like pollen viability (91.3 & 87.4 %) and spikelet fertility (84.3 & 75.9 %) and grain yield (7744.8 & 6531.3 kg ha^{-1}). Among the genotypes GNV-10-89 (10270.9 kg ha^{-1}) recorded the higher grain yield and lower was observed in BPT-5204 (3937.5 kg ha^{-1}) these results conclude that the late *Kharif* transplanting was not suitable for this region as there was sharp drop-down of temperature (14.1°C) at a reproductive stage which leads to high spikelet sterility. By looking at the results obtained, among four genotypes GNV-10-89 recorded high grain yield followed by GNV-1108 these two genotypes are considered as moderately tolerant, GNV-1801 is moderately sensitive and BPT-5204 is sensitive to low-temperature stress.

Keywords: Low temperature stress, Rice crop, Reproductive stage, Phenological traits and Grain yield

INTRODUCTION

Energy is the sole prerequisite for maintaining the organism's structural integrity over its lifetime. A plant's ability to function normally and maintain its health can be hampered by several forms of stress such as salt, dryness, extreme high or low temperatures and heavy metals. The results of this study shed light on the effects of low temperature stress on the morpho-physiological and phenological characteristics and yield of rice crops. Extreme weather conditions are thought to be responsible for 18-43% of the yield changes between years (Vogel *et al*., 2019). The rice crop native to tropical and subtropical regions need temperature between 20°C to 40°C to grow reported by Sridevi and Chellamuthu (2015). According to Susanti *et al*. (2019) in a field experiment, rice spikelet sterility can reach 89.7% when exposed to low temperature during the flowering stage when compared to varieties that are resilient to the stress condition. Even though the best time to rice plant varies depending on the genotype, region and location, it is crucial to choose the right timing for sowing and transplanting to have a high grain yield (Deshmukh and Patel, 2013). It was also reported that cold stress delays

phenological development and increases spikelet sterility, resulting in low yield (Farrell *et al.*, 2001; Lee, 2001 and Gunawardena *et al.*, 2003). All phenological stages of rice are impacted by exposure to cold temperature, which also results in decreased grain filling and grain yield. Low temperature during vegetative stage might result in sluggish growth, reduced seedling vigour, fewer seedlings, less tillering, higher plant mortality, prolonged growth periods and an earlier reproductive stage (Ali *et al.*, 2006; Fujino *et al.*, 2004). Low temperature stress has an impact on the phenology, spikelet sterility and yield of *Kharif* rice. Early seeding followed by regular sowing resulted in a noticeably better grain production. The maximum grain production among the cultivars was obtained by JGL-1798 (short duration), followed by JGL-384. When sown early, the long-duration variety BPT-5204 provided noticeably larger yields and when sowings were postponed, grain yields gradually decreased. Compared to minimum temperatures from panicle initiation to 50% flowering and 50% flowering to maturity, the minimum temperature at flowering was significantly and favourably linked with yield (Dakshina Murthy and Upendra Rao, 2010). The rice varieties used in this experiment BPT-5204 and GNV-1801 were long duration varieties whereas GNV-10-89 and GNV-1108 were short duration varieties.

The current investigation was carried out in Tunga Bhadra Command Area (TBCA), where farmers in the Gangavathi region were getting water later than farmers in other TBCA regions. As a result, paddy (rice) planting was delayed until late *Kharif.* To determine the impact of low temperature on late *Kharif* planting, we used two varieties with short durations and two varieties with long durations. In this experiment, the varieties BPT-5204, GNV-1801 (long duration), GNV-10-89, and GNV-1108 were employed (short duration). The reproductive stage of long duration varieties transplanted in late *Kharif* (30th September) experienced a sharp drop in temperature that is in the month of December the minimum temperature was 14.1^{o}C which severely affected the grain filling stage of rice crop.

MATERIALS AND METHODS

To understand the morpho-physiological and phenological characterization of rice varieties for low temperature stress tolerance, a field experiment was conducted during the *Kharif* (15th September) and late *Kharif* (30th September) seasons of 2020-21 and 2021-22 at the Agricultural Research Station, Gangavathi, University of Agricultural Sciences, Raichur, Karnataka located at an altitude of 419 metres above mean sea level. Two factorial randomised block design was used for the field experiment, with factor one being the dates of transplanting and factor two being the varieties with three replications. For this field experiment, four distinct varieties (BPT-5204, GNV-1801, GNV-10-89, and GNV-1108) were chosen. These cultivars came from the University of Agricultural Sciences, Raichur, Karnataka's AICRP on Rice, Gangavathi Agricultural Research Station.

Abbreviations:

GNV - Gangavathi
AICRP - All India Coordinated Research Project
DAT- Days after transplanting
CD - Critical difference; SEm. - Standard error of the mean; CV - Coefficient of variation
DPI - days to panicle initiation; DF - days to 50% flowering; DPM - days to physiological maturity
DHM - days to harvestable maturity; ARS - Agriculture Research Station

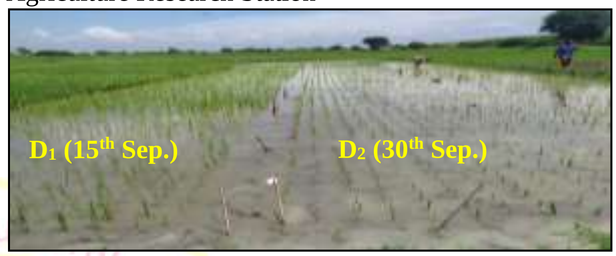

Plate 1. Transplanting of 25 days old paddy seedlings in the main field at two different dates *i.e.*, D_1 & D_2 (15th and 30th September) for the experimental year 2020-21

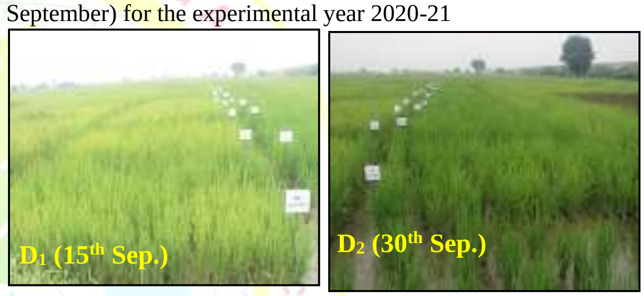

Plate 2. Crop at 65 DAT in D_1 and D_2 (15th and 30th September) for the experimental year 2020-2021

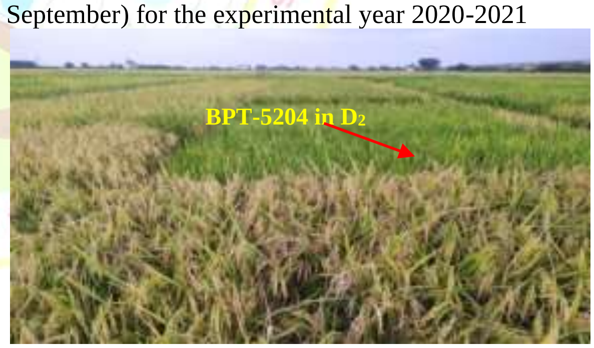

Plate 3. BPT-5204 in D_2 at 95 days after transplanting encounters the low temperature

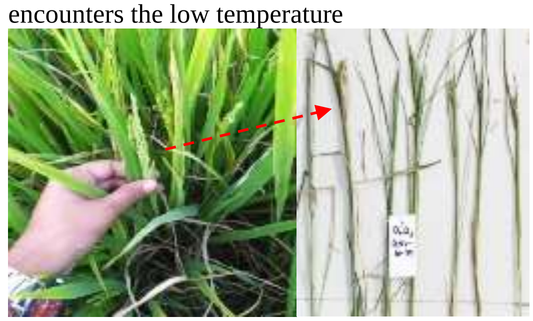

Plate 4. Incomplete panicle exsertion in BPT-5204 due to late *Kharif* planting (D_2)

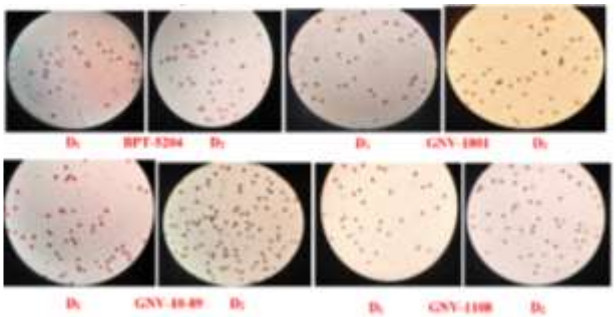

Plate 5. Pollen viability of different rice varieties in two dates of transplanting (D1 & D2) for the experimental year 2020-21

RESULTS AND DISCUSSION

Morphological traits

The data on morphological traits such as plant height, number of green leaves, number of productive tillers, total dry matter production, root length and total leaf area recorded at flowering stages (95 DAT) under two distinct transplanting dates and four varieties presented in the Table 1. With respect to dates of transplanting plant height, number of green leaves, number of productive tillers and total dry matter production were significantly higher in D_1 (101.6 cm, 21.5 hill^{-1}, 14.5 hill^{-1} and 29.1 g hill^{-1},) than D_2 (99.76 cm, 16.1 hill^{-1}, 11.5 hill^{-1} and 21.1 g hill^{-1}). Among the varieties GNV-10-89 showed higher plant height, productive tillers and total dry matter (111.8 cm, 16.0 hill^{-1} and 32.7 g hill^{-1}) which was accompanied by GNV-1108 (104.0 cm, 14.3 hill^{-1}, 26.9 g hill^{-1}). The lower plant height, number of productive tillers and total dry matter was observed in BPT-5204 (85.7 cm, 10.1 hill^{-1} and 18.2 g hill^{-1}). Number of green leaves, total leaf area and root length was higher in BPT-5204 (25.5 hill^{-1}, 5.07 dm^2 hill^{-1} and 18.1cm) this might be due to low temperature, reduced sunshine hours and cloudy weather leads to decreased transpiration rate and reduced senescence process. Among the interactions D_1V_3 showed higher plant height, number of productive tillers, total dry matter production (112.0 cm, 17.4 hill^{-1}, 39.4 g hill^{-1}) and D_2V_1 recorded the lower (85.1 cm, 8.9 hill^{-1}, 15.6 g hill^{-1}). Number of green leaves was higher in the interaction D_1V_1 (30.1 hill^{-1}) and lower in D_2V_4 (10.3 hill^{-1}) whereas, total leaf area and root length was higher in D_2V_1 (5.34 dm^2 hill^{-1} and 20.2 cm) and lower was observed in D_1V_4 (2.55 dm^2 hill^{-1} and 13.4 cm).

Seedling growth rate increases linearly between 22-31ºC temperatures. Critical low temperature required for shoot and root elongation about 12-16ºC therefore optimum transplanting date and suitable varieties may have considerable impact upon crop production. In the present experiment the plant height increased actively from 65 to 95 DAT but the marginal increase in plant height was observed from 95 DAT up to harvest. The maximum plant height was recorded in *Kharif* (D_1) than late *Kharif* (D_2) due to incidence of low temperature at late *Kharif* (30th September). The time of transplanting ensures the complete synchronization between vegetative and reproductive phases on one hand and climatic rhythm on the other hand. Therefore, the plant height recorded in the present experiment was in line with the findings of Kumar and Surendar (2019) they screened out 22 rice cultivars for low temperature stress tolerance through the physiological and biochemical responses the maximum plant height varied with different growth stages among 22 rice cultivars. The temperature drops down to 10°C during seedling establishment such low temperature significantly reduced seedling growth and establishment (Humphreys *et al.,* 1996). Due to low temperature stress reduced plant height was observed in BPT-5204 reported by Pradhan *et al*. (2017). Number of green leaves reduced from 65 DAT to harvest, in *Kharif* (D_1) number of green leaves were higher where as in late *Kharif* (D_2) number of green leaves recorded lower. The vegetative growth prolonged and the genotype BPT-5204 recorded more number of green leaves in late *Kharif* and thereafter declined due to the process of senescence at harvest. The results were in line with the findings of Kumar and Surendar (2019) who reported that, the number of green leaves per plant were more at 30 and 60 DAT in different varieties. Reyes *et al*. (2003) suggested that rice growth in the temperate regions was constrained by the limited period that favours growth where it needs optimum temperature between 25°C to 35°C and temperatures below this often result in poor seedling vigour. The optimum temperature required for tillering was 25ºC - 31ºC, tillering rate inhibited by low temperature due to which the period of tillering prolonged. The low temperature stress decreases the uptake of solutes by root owing to which water balance disturbed leading into more transpiration as compared to water absorption due to loss of water which resulted in leaf curling and reduced photosynthetic rate. In this experiment *Kharif* (D_1) recorded maximum number of productive tillers than late *Kharif* (D_2) at 95 DAT. Kuroki *et al*. (2007) stated that rice is a cold sensitive crop that has its origin in tropical or sub-tropical areas and low temperatures dramatically reduce its production and low temperature at the early stages of development inhibits seedling establishment due to which the crop establishment will be non-uniform. Among the varieties a greater number of productive tillers observed in GNV-10-89 followed by GNV-1108 because these two varieties showed low temperature stress tolerance whereas BPT-5204 and GNV-1801 recorded less number of productive tillers as they were low temperature stress sensitive varieties. The similar results were obtained by Kaneda and Beachell (1974) who noticed that, the types of low temperature effects on seedlings can be manifested as poor germination, slow growth and discolouration or yellowing, withering after transplanting, reduced tillering and stunted growth. Farzin *et al*. (2013) who found that rice plant was sensitive to low temperature stress. Maximum total dry matter production was recorded in GNV-10-89 at D_1 (*Kharif*) while the less was observed in BPT-5204 at D_2 (late *Kharif*). These results were in line with the findings of Aghaee *et al*. (2011)

found that, the quantitative changes of dry matter, were determined in cold sensitive rice genotype (Hoveizeh) in comparison with check genotype (IRCTN34, cold tolerant), treatment plants were exposed to 15/10°C (day/night) cold stress for two weeks and control plants were kept at 29/22°C (day/night) and 12 hours photoperiod. Dry matter accumulation decreased due to low temperature stress in both varieties. Cold tolerant genotype showed increased accumulation of total dry matter in rice seedlings where as cold-sensitive genotype showed less values. Higher leaf area was recorded in *Kharif* (D_1). However, lower leaf area reported in late *Kharif* (D_2). This might be due to the congenial environmental conditions *i.e.*, the average temperature (21-37 ºC) throughout the crop growth period and prolonged sunshine hours that prevailed during *Kharif* (D_1) transplanting date. Variation among the varieties in respect of leaf length, width and leaf area appeared due to genotypic variation. GNV-10-89 and GNV-1108 recorded higher leaf area at all growth stages. The decrease in the overall growth of rice plants due to changes in physical characteristics of the structural system of cells and alteration in the metabolic reactions that affect physiological processes. The reduction in leaf area subjected to low temperature stress under delayed transplanting in conformity with earlier studies (Nagasuga *et al*., 2011) the effect of low root temperature on rice growth in relation to dry matter production, root water uptake and leaf area. They found that, the low root temperature inhibited dry matter production of rice plants by decreasing the leaf area where the response of leaf area was affected by changes in plant water status. The higher root length was noticed in GNV-10-89 at D_1 (*Kharif*) at initial growth stages where as the lesser root length was observed in BPT-5204 at D_2 (late *Kharif*). Since the plant growth gradually advances the root length decreased in GNV-10-89 as it is a short duration genotype. Hence shoot length was increased whereas root length decreased significantly. BPT-5204 recorded maximum root length at 95 DAT due to the effect of low temperature, less humidity and lower sunshine hours the senescence process was slower. The similar results were obtained by Kumar and Surendar (2019) they found that among 22 rice varieties BPT-5204 recorded high root length.

Physiological traits

The result obtained on photosynthetic rate and transpiration rate at 95 DAT presented in the Table 1. The significantly higher photosynthetic rate and transpiration rate was recorded in D_1 (14.55 μ moles CO_2 m^{-2} s^{-1} and 12.86 m moles H_2O m^{-2} s^{-1}) as compared to D_2 (13.45 μ moles CO_2 m^{-2} s^{-1} and 11.01 m moles H_2O m^{-2} s^{-1}). Among four varieties, GNV-10-89 (15.20 μ moles CO_2 m^{-2} s^{-1} and13.64 m moles H_2O m^{-2} s^{-1}) recorded significantly maximum photosynthetic rate and transpiration rate respectively, which was on par with GNV-1108 (14.10μ moles CO_2 m^{-2} s^{-1} and 12.54 m moles H_2O m^{-2} s^{-1}) and the minimum photosynthetic rate was noticed in GNV-1801 (13.19 μ moles CO_2 m^{-2} s^{-1}) followed by BPT-5204 (13.52 μ moles CO_2 m^{-2} s^{-1}). The differences in photosynthetic rate and transpiration rate were not significant between interaction effect both in transplanting dates and varieties.

These results were in line with the findings of Ahmed *et al*. (2011) who reported reduction in photosynthetic efficiency and stomatal conductance and ultimately lower yield under variable weather conditions. Photosynthetic efficiency could be improved by exposure to favourable environments and optimizing transplanting date. The stress caused by low temperature could lead to reduced physiological activity of crop plants which reduces permeability of cell membrane in water uptake, in this study late *Kharif* transplanting showed reduced net photosynthesis this might be due to low temperature stress decreased metabolic activity of the root cells, earlier research showed reduced leaf growth and in turn the leaf area in many species of plant (Farooq *et al*., 2009). Among the varieties higher photosynthetic rate was seen in GNV-10-89 at critical growth stages due to high leaf area, favourable temperature, prolonged sunshine hours and photoperiod. BPT-5204 possessed relatively lower photosynthetic rate. The similar results were obtained by (Prasad *et al*., 1994; Ribascarbo *et al*., 2000) who found that, the cold stress in rice reduces the photosynthesis activity by reducing the chlorophyll content. Transpiration rate, an important indicator of physiological characters strongly influenced under continuously changing climatic scenarios like temperature, humidity and light intensity and crop internal factors including stomatal aperture and hydraulic status of plant. The present study revealed that higher transpiration rate led to water circulation and optimum photosynthetic efficiency which consequently increased yield in *Kharif* (D_1). Likewise, Li *et al*. (2004) revealed that, the low temperature deteriorated plant growth, chlorophyll content, net photosynthetic rate stomatal conductance, intercellular CO_2 and transpiration rate in zoysia grass. Genotype GNV-10-89 showed adaptability measures to cope stress and environmental constraints as compared to BPT-5204 and GNV-1801. Higher transpiration rate reflected in high dry matter and grain yield in GNV-10-89.

Phenological traits

The data with respect to number of days to PI (panicle initiation), FF (50 % flowering), PM (physiological maturity) and HM (harvestable maturity) presented in the Table 2. Late *Kharif* transplanting that is D_2 took a greater number of days (90.5 days, 102.3 days, 127.2 days and135.4 days) to PI, FF, PM and HM respectively was differed significantly from D_1 (80.6 days, 98.3 days, 116.7 days and 124.7 days). Among varieties GNV-10-89 (79.2 days, 88.3 days, 109.8 days and 118.9 days) took significantly less number of days for PI, FF, PM and HM respectively, which was on par with GNV-1108 (79.4 days, 89.2 days, 109.1 days and118.8 days), BPT-5204 (92.4 days, 114.8 days, 135.1 days and141.7 days) taken more number of days for PI, FF, PM and HM respectively, followed by GNV-1801 (91.2 days, 108.8

days, 133.8 days and 141.0 days). The influence of interactions was non-significant for days required to PI and FF whereas, PM and HM differed significantly where in D_2V_1 (138.5 days and 145.4 days) took a greater number of days to PM and HM and less number of days to PM and HM was noticed in the interaction D_1V_3 (102 days and 111.5 days). Delay in transplanting of *Kharif* rice (D_2) took more number of days to phenological characters such as days to panicle initiation, days to 50% flowering, days to physiological maturity and days to harvestable maturity as influenced by low temperature stress. Temperature is one of the major factors influencing crop growth, which cannot be manipulated under field conditions. In this study panicle initiation, 50% flowering, physiological maturity and harvestable maturity took more number of days in late *Kharif* (D_2) planting as compared to *Kharif* (D_1). According to Shi *et al*. (2021) reported chilling treatment (15ºC) at booting to flowering stage for 8 days, delayed flowering date by 5 days as compared to the control. The intensity and duration of low temperature at the booting and flowering stage affected the phenology and grain yield of rice. Low temperature stress lengthened the growth period of rice but decreased the grain yield by reducing the sink capacity. The varieties exposed to low temperature stress condition at booting and flowering stages reduced the spikelet fertility and the grain number per panicle, which led to considerable yield loss in delayed planting.

Reproductive traits

The data pertaining to pollen viability and spikelet fertility presented in Table 2 and differed significantly among the dates of transplanting, varieties and interactions. The transplanting date D_1 (91.3 % and 84.3 %) showed significantly higher pollen viability and spikelet fertility as compared to D_2 (87.4 % and 75.9 %). Among varieties GNV-10-89 (94.1 % and 85.7 %) showed higher pollen viability and spikelet fertility which was on par with GNV-1108 (91.3 % and 83.4 %).

Table 1. Effect of low temperature on morpho-physiological traits of rice varieties in two dates of transplanting at reproductive stage

Treatments	Plant height (cm)	No. of green leaves hill^{-1}	No. of productive tillers hill^{-1}	Total dry matter (g hill^{-1})	Total leaf area (dm^2)	Root length (cm)	Photosynthetic rate (µ mole CO_2 m^{-2} s^{-1})	Transpiration rate (m mole H_2O m^{-2} s^{-1})
	Days after transplanting (DAT) Pooled (2020-21 and 2021-22)							
	95 DAT	95 DAT	95 DAT	95 DAT	95 DAT	95 DAT	95 DAT	95 DAT
	Transplanting dates							
D_1	101.6	21.5	14.5	29.0	3.79	14.6	14.55	12.86
D_2	99.76	16.1	11.5	21.1	4.11	18.2	13.45	11.01
S.Em.±	0.42	0.47	0.26	0.45	0.09	0.18	0.13	0.06
C.D. at 5%	1.29	1.43	0.81	1.37	0.28	0.55	0.39	0.19
	Varieties							
V_1	85.7	25.5	10.1	18.2	5.07	18.1	13.52	10.03
V_2	102.6	19.5	11.8	22.3	4.14	16.9	13.19	11.52
V_3	111.8	16.9	16.0	32.7	3.74	15.7	15.20	13.64
V_4	103.9	13.3	14.3	26.9	2.84	14.9	14.10	12.54
S.Em.±	0.59	0.66	0.37	0.63	0.13	0.25	0.18	0.06
C.D. at 5%	1.82	2.03	1.14	1.94	0.39	0.77	0.55	0.20
	Interactions							
$D_1 V_1$	86.3	30.1	11.2	20.8	4.80	16.1	14.33	10.69
$D_1 V_2$	102.6	21.4	13.3	25.5	4.14	15.0	13.59	12.53
$D_1 V_3$	112.0	18.3	17.4	39.4	3.66	14.1	15.61	14.62
$D_1 V_4$	103.7	16.2	16.0	30.2	2.55	13.4	14.67	13.60
$D_2 V_1$	85.1	20.7	8.9	15.6	5.34	20.2	12.71	9.37
$D_2 V_2$	102.7	17.6	10.4	19.1	4.14	18.9	12.79	10.50
$D_2 V_3$	111.6	15.4	14.5	26.0	3.83	17.4	14.80	12.65
$D_2 V_4$	104.2	10.3	12.5	23.6	3.11	16.4	13.53	11.52
S.Em.±	1.09	0.93	0.53	0.89	0.18	0.36	0.26	0.12
C.D. at 5%	NS	2.87	NS	2.74	NS	NS	NS	NS
C.V.	1.45	8.67	7.05	6.19	8.08	3.70	3.03	1.36

V1-BPT-5204; V2-GNV-1801; V3-GNV-1089; V4-GNV-1108; D2: (Late Kharif = 30-09-2020 & 21); D1: (Kharif = 15-09-2020 &21); F.W. - Fresh weight NS- Non-significant, Data analysed by using ICAR-WASP

Table 2. Effect of low temperature on phenological traits and yield of rice varieties in two dates of transplanting

Treatments	Days to Panicle initiation	Days to 50% flowering	Days to Physiological maturity	Days to Harvestable maturity	Pollen viability (%)	Spikelet fertility (%)	Grain yield (kg ha^{-1})
	Days after transplanting (DAT)						
	Transplanting dates						
D_1	80.6	98.3	116.7	124.7	91.3	84.3	7744.8
D_2	90.5	102.3	127.2	135.4	87.4	75.9	6531.3
S.Em.±	0.36	0.58	0.34	0.29	0.17	0.61	95.0
C.D. at 5%	1.09	1.79	1.04	0.89	0.54	1.86	290.9
	Varieties						
V_1	92.4	114.8	135.1	141.7	85.0	75.2	3937.5
V_2	91.2	108.8	133.8	141.0	87.2	76.0	5531.3
V_3	79.2	88.3	109.8	118.9	94.1	85.7	10270.9
V_4	79.4	89.2	109.1	118.8	91.3	83.4	8812.5
S.Em.±	0.50	0.83	0.48	0.41	0.25	0.86	134.4
C.D. at 5%	1.54	2.54	1.47	1.26	0.77	2.63	411.5
	Interactions						
D_1V_1	87.0	111.2	131.7	138.0	88.6	81.2	4625.0
D_1V_2	86.9	106.4	130.3	137.0	89.7	78.7	5958.3
D_1V_3	74.2	87.4	102.7	111.5	94.9	90.5	11000.0
D_1V_4	74.3	88.4	102.0	112.4	92.3	87.0	9395.9
D_2V_1	97.7	118.5	138.5	145.4	81.4	69.3	3250.0
D_2V_2	95.5	111.2	137.2	144.8	84.7	73.4	5104.2
D_2V_3	84.2	89.4	116.9	126.2	93.3	81.1	9541.7
D_2V_4	84.5	90.0	116.2	125.2	90.3	79.8	8229.2
S.Em.±	0.71	1.17	0.68	0.58	0.35	1.21	190.0
C.D. at 5%	NS	NS	2.08	1.78	1.08	NS	NS
C.V.	1.44	2.02	0.96	0.79	0.69	2.62	4.61

V1-BPT-5204; V2-GNV-1801; V3-GNV-1089; V4-GNV-1108; D2: (Late Kharif = 30-09-2020 & 21); D1: (Kharif = 15-09-2020 &21); F.W. - Fresh weight NS- Non-significant
Data analysed by using ICAR-WASP

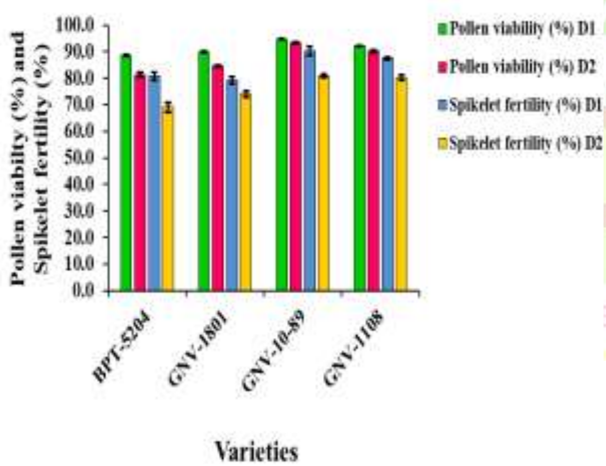

Figure 1. Effect of low temperature on pollen viability and spikelet fertility of rice varieties in two dates of transplanting
D_1-*Kharif* (15th September) & D_2-Late *Kharif* (30th September); standard error has been calculated and included in the graph

Significantly lower pollen viability and spikelet fertility was recorded in BPT-5204 (85.0 % and 75.2 %) followed by GNV-1801 (87.2 % and 76.0 %). The interaction effects showed significant differences where, the interaction between D_1V_3 (94.9 %) recorded significantly higher pollen viability whereas the interaction D_2V_1 (81.4 %) recorded less pollen viability. The influence of interactions effect showed non-significant differences with respect to spikelet fertility. Pollen viability, greatly contribute to the spikelet fertility these two components are directly proportional to each other. In this research higher pollen viability and spikelet fertility was recorded in *Kharif* (D_1) as compared to late *Kharif* (D_2).

Between varieties higher pollen viability and spikelet fertility was observed in GNV-10-89 and GNV-1108 as compared to BPT-5204 and GNV-1801) due to delayed planting where the reproductive stage affected by reduced temperature in December 3rd week (14.1°C) The fertilization stage from pollen maturation to the completion of fertilization is sensitive to low temperature. These results agreed with the findings of Satake (1989) who reported that, low temperature at the booting stage has also been reported to cause degeneration of young microspores and dissolution of tapetal cells, interrupting or decreasing the supply of nutrients from the anther walls to the pollens. According to Ye *et al*. (2009) yield losses due to cold temperature resulted in incomplete pollen formation and subsequent floret sterility also Andaya and Mackill (2003) reported that, low temperature affects rice cultivation mainly in two stages of development *i.e.*, seedling and booting. In these stages cold temperature has harmful effects on crop productivity.

Apart from the two critical stages, low temperature stress can also be manifested at different growth stages such as germination, seedling, vegetative, reproductive, and grain maturity. Suzuki *et al*. (2008) reported that the

effects of cold stress at the reproductive stage of plants delay heading and result in pollen sterility, which is thought to be one of the key factors responsible for the reduction in grain yield of crops. Similarly, Suh *et al*. (2010) found that, the cold stress has many negative impacts on the productivity of rice cultivars like it reduces growth of seedling, weakens photosynthetic ability, reduces plant height, delays days to heading, reduces spikelet fertility and cause poor grain quality. According to Cruz *et al*. (2006) the effect of low temperature was investigated in six rice varieties at 17°C at two reproductive stages (microsporogenesis and anthesis). Low temperature tolerance was measured as the percentage of reduction in panicle exsertion and in spikelet fertility.

Grain yield (kg ha^{-1})

The results obtained with respect to grain yield were differed significantly among transplanting dates and varieties presented in the Table 2. The significantly higher grain yield was found in D_1 (7744.8 kg ha^{-1}) as compared to D_2 (6531.3 kg ha^{-1}). Among varieties the significantly more grain yield was obtained in GNV-1089 (10270.9 kg ha^{-1}) which was on par with GNV-1108 (8812.5 kg ha^{-1}) while the lower grain yield found in BPT-5204 (3937.5 kg ha^{-1}) followed by GNV-1801 (5531.3 kg ha^{-1}). The interaction effects were non-significant with respect to grain yield. Low temperature (< 20°C) delays rice seedling establishment, hampers tiller formation, affects flowering, causes panicle sterility and finally leads to lower grain yield (Hussain *et al*., 2019). Late *Kharif* (D_2) recorded the lower grain yield as compared to *Kharif* (D_1). BPT-5204 and GNV-1801 recorded less grain yield as compared to GNV-10-89 and GNV-1108. These results were in line with the report of Kumar and Surendar (2019) in their experiment they used 22 rice varieties including BPT-5204 rice seedlings were transplanted in the main field during late *Kharif* season. BPT-5204 showed lesser grain yield compared to all remaining varieties due to the effect of low temperature in delayed planting. Wainaina *et al*. (2015) also evaluated eight NERICA rice varieties for cold tolerance at reproductive stage and compared with their parents and three Japanese standard rice varieties over 3 years. Cold tolerance was evaluated based on the filled grain ratio (FGR) after cold water irrigation. NERICA 1, 2 and 7 showed significantly better performance than NERICA 3 and 4, while NERICA 6, 15 and 16 performed poorly under cold water irrigation. The Japanese varieties Koshihikari (tolerant) and Ozora (moderately tolerant) were more affected by cold water irrigation than NERICA 1, 2 and 7. According to (Shah *et al*. 2011) due to environmental constraints, it is estimated that rice yield will decline by 41% through the end of this century.

CONCLUSION

On the basis of above findings, it can be concluded that the overall physiological performance of rice crop in relation to morpho-physiology and phenology was affected with delayed planting. Low temperature stress resulted in reduced prolonged vegetative growth and more chaffy grains in the BPT-5204 genotype. Based on major growth parameters and grain yield affected in late *Kharif* planting the four rice varieties used in this experiment were categorized into sensitive and tolerant to low temperature stress such as GNV-10-89 and GNV-1108 moderately tolerant, GNV-1801 moderately sensitive and BPT-5204 sensitive to low temperature stress especially at reproductive stage.

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Research Article

Identification of *Colletotrichum* species associated with anthracnose disease of chilli in major chilli growing area of India

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ABSTRACT
Anthracnose fruit-rot samples were randomly collected from 95 chilli farms grown in different hotspot regions from following states. Survey was conducted during Kharif 2020 from Andhra Pradesh, Karnataka, and Tamil Nadu, while during Kharif 2021 from Maharashtra, Madhya Pradesh, and Chhattisgarh. Samples were analyzed based on morphological characters. After morphological characterization of collected samples, it was confirmed that 80 fields were infected alone with *C. capsici*, 7 fields were infected alone with *C. gloeosporioides* while 8 fields were mixed infected with both *C. capsici* and *C. gloeosporioides*. Anthracnose infection mainly affects chilli at red fruit stage. Morphological characterization of collected samples from the surveyed region revealed that *Colletotrichum capsici* and *C. gloeosporioides* were the major species infecting chilli while *Colletotrichum capsici* was the predominant species. As *C. capsici* is predominant species causing Anthracnose, we need anthracnose resistant source at least against *C. capsici*. Resistant source against both C, capsici and *C. gloeosporioides* will be a boon for breeders to strengthen disease resistance
Keywords: Anthracnose, Fruit rot, Anthracnose Die-back, *Colletotrichum*, *C. capsici*, *C. gloeosporioides*, *C. acutatum*,

INTRODUCTION

Chilli, *Capsicum* annum (L.) is one of the most important spices and vegetable crop throughout the world including India. It is one of the most widely cultivated among *Capsicum* species comprises of both pungent chilli as well as sweet (bell pepper) of numerous shapes and sizes. It is a good source of Vitamin A and C, potassium, and folic acid (Pathirana 2012). Chilli is widely used as vegetable, spice, and condiments, it is also used in medicines and beverages.

India is the world's largest producer of dried chillies and in 2021 India produced 2.05 million tons, out of 4.84 million tons produced worldwide (FAOSTAT 2021). India is not only the largest producer but also the largest consumer and exporter of chilli in the world. Chilli alone contributes 36.4 % to the total spice export quantity of the country (Spice Board, 2022) and contributes 42.34% of world chilli production followed by Bangladesh, Thailand, China, Ethiopia (FAOSTAT 2021). In India during year 2021-22, Andhra Pradesh tops the list in dry chilli production of 7 lakh tonnes covered under 1.6 lakh hector with 4375 kg/ha productivity followed by Telangana, Madhya Pradesh, Karnataka, Odisha, Tamil Nadu and Maharashtra. Guntur district in Andhra Pradesh produces 15% of all the chillies produced in India and the state of Andhra Pradesh individually contributes 43.71% of India's chilli production (Spice Board, 2022).

The sustainability of chilli is affected by various abiotic and biotic stresses poses hurdle for successful large-scale commercial cultivation to farmers and seed industries. Chilli is susceptible to various viral, bacterial, and fungal diseases. Among these Anthracnose (fruit rot) is most widespread and economically important fungal disease and is known to cause by one of the four species of *Colletotrichum* viz. *C. capsici*, *C. gloeosporioides*, *C. acutatum* and *C. coccodes* in solo or as disease complex (Simmonds, 1965; Johnston and Jones, 1997; Kim et al., 1999; Nirenberg et al., 2002; Voorrips et al., 2004; Sharma et al., 2005; Pakdeevaraporn et al., 2005; Than et al., 2008). The disease was reported for the first time in India from Coimbatore of Madras Presidency (Sydow, Butler & Bisby 1913). *Colletotrichum capsici* can cause disease on almost all parts of the Chilli plant during any stage of plant growth. Anthracnose has been observed to infect chilli crop in three phases viz. (i) seedling blight / damping off stage, prevalent in the nursery, (ii) die back stage which is initiated at different growth stages and (iii) fruit rot stage where majorly ripe fruits are infected.

Chilli anthracnose usually develops under high humid conditions especially in the rainy season. The disease is mainly a problem on mature fruits, causing severe losses up to 84% (Thind and Jhooty, 1985) due to both pre- and post-harvest fruit decay (Hadden and Black, 1989; Bosland and Votava, 2003). The severity of the disease varies depending on cultivars grown and the weather conditions prevailing in a particular region. The disease is both seed borne and air borne and affects seed germination and vigour to a greater extent (Ahmed, 1982; Perane and Joi, 1988; Mesta, 1996 and Asalmol et al., 2001). Economic losses caused by the disease are mainly attributed to lower fruit quality and marketability.

The disease is more severe in India because of its complex nature. In the recent climate change situation, there is a need to investigate the disease thoroughly, as epidemics vary in different regions giving scope for understanding the extent of variability in pathogen population. To identify the resistant germplasm for Anthracnose, the geographical mapping along with Cataloguing and assortment of *Colletotrichum* species using morphological characterization is of prime importance. Further, their confirmation using molecular markers is a more reliable technique and can give a logical conclusion regarding the genetic variability existing among isolates. Hence, an extensive survey was conducted in Kharif 2020 and Kharif 2021 at South and Central India respectively to assess the incidence of anthracnose of chilli.

MATERIALS AND METHODS

The research activities and laboratory experiments were carried out during 2019 to 2022 in the Department of Plant Pathology, Ankur Breeding Support Centre, Ankur Seeds Pvt. Ltd., Nagpur. Nagpur is situated at centre of India and of Maharashtra state at 21°9′N 79°5′E and at an altitude of 370.0 Ft. above mean sea level.

Survey

Major red chilli growing states in India are Andhra Pradesh, Madhya Pradesh, Telangana, Karnataka, Tamil Nadu, and Maharashtra where it was grown in 5.23 lac hectors in year 2021-22 (Data Source: Spice Board 2021-22) which contributes approximately 75.25% red chilli growing area in India. Thus, an extensive survey was conducted in Central and Southern part of India to for geographical mapping of *Colletotrichum* Species causing chilli anthracnose. Anthology of different *Colletotrichum* isolates causing Anthracnose fruit rot was done during Kharif 2020 from Andhra Pradesh, Karnataka, and Tamil Nadu while in Kharif 2021 from Maharashtra and Madhya Pradesh. Chilli samples infected with Anthracnose fruit-rot were randomly collected from 95 locations grown in different hotspot regions from above states.

Isolation

Infected chilli fruits showing typical anthracnose symptoms, sunken necrotic tissues, with concentric rings of conidial masses on chilli fruits were selected for isolation. Five individual fruits per location were subjected for pathogen isolation. Isolation was carried out using infected tissue and, in some cases, (where saprophytic infection was more on outer tissue) by Blotter method (ISTA,2005). Surface sterilised (0.1% $HgCl_2$ for 1 min) infected tissue (~3-5 mm) was cultured on Potato Dextrose agar plates. After incubation for 3-4 days fungal hyphae grown were subcultured onto PDA plates (PDA, Himedia). In Blotter method infected seeds were placed on moist blotter paper microchamber and were incubated at 25°C ± 2 for seven days. Further fungal hyphae grown on filter paper was subcultured onto potato dextrose agar plates. Inoculated plates were incubated at 25°C ± 2 for 8-10 days in alternative 12 hours of darkness and 12 hours of light. Cultures were isolated, maintained and preserved for further study at Plant Pathology Laboratory at Breeding Support Centre of Ankur Seeds Pvt. Ltd. Nagpur (Maharashtra).

Morphological Characterization

Morphological colony characters of the fungus were observed on incubated PDA plates. Cultures developed perithecia on media were selected for microscopic analysis. Individual sample-wise slides were prepared and stained with lactophenol cotton blue. Conidial morphology was examined with the help of binocular microscope (Leica, Germany: DM6000B). Conidial size of each sample was measured using Leica Q-Win Software package. Categorisation of *Colletotrichum* species was done based on conidial shape. However, this result needs to be confirmed using molecular markers to avoid misidentification of the species.

DNA Extraction and Molecular confirmation using PCR

Genomic DNA from all the 103 isolates were extracted using Dellaporta DNA extraction method (Dellaporta et. al. 1983), from fresh mycelial mat grown on Potato Dextrose Broth following the standardized protocol. DNA quality was assessed on a 0.8% (w/v) agarose gel, quantified by comparing with a known amount of Lambda DNA, diluted to 2 ng/µL and then stored at -20 °C until ready for PCR. PCR detection by species-specific primers for *Colletotrichum capsici* (Torres-Calzada et. al. 2011), *Colletotrichum gloeosporioides* (Tapia-Tussell et al 2008) (Talhinhas et al 2002) (Mills et al 1992) (White et al 1990) and *Colletotrichum acutatum* (Freeman et al. 2000) and (Afanador et al. 2003) was conducted using following species-specific Primers (Table 1).

For molecular confirmation, genomic DNA of 103 isolates of *Colletotrichum* species were amplified by PCR separately with 3 species-specific primers of *C. capsici, C. gloeosporioides and C. acutatum* (Table 1). PCR reactions were performed in 96 well plate with 20µl volume. The constituents of reaction mixture are mentioned in Table 2.

Table 1. *Colletotrichum* species and their primer pair sequence with expected amplicon size.

Organism	Sequence		Expected Amplicon
C. capsici	C cap-F	5'-GTAGGCGTCCCCTAAAAAGG-3'	394
	C cap-R	5'-CCCAATGCGAGACGAAATG-3'	
C. gloeosporioides	Cg INT-F	5'-GGCCTCCCGCCTCCGGGCGG-3'	450
	ITS-4-R	5'-TCCTCCGCTTATTGATATGC-3'	
C. acutatum	Ca INT-2-F	5'-GGGGAAGCCTCTCGCGG-3'	490
	ITS-4-R	5'-TCCTCCGCTTATTGATATGC-3'	

Table 2. Constituents of PCR reaction Mixture.

Initial Concentration	Component	Volume	Final Concentration
	Template DNA	1.2 µl	100 ng/µl
10 X	PCR buffer	2 µl	1 X
25 mM	MgCl2	1.6 µl	1.5 mM
10 mM	dNTPs	0.5 µl	200 µM
10 µM	Forward primer	0.5 µl	0.2 µM
10 µM	Reverse primer	0.5 µl	0.2 µM
1 Unit	Taq DNA polymerase	1 µl	1 U/µl
10 X	BSA	1 µl	1 X
	Nuclease Free Water	11.7 µl	

PCR reactions conditions for the amplification were standardized for the primer and thermal cycler. The following amplification program was used for desired amplicon:

Table 3. PCR Conditions for respective species-specific primer pair.

	C. capsici		*C. gloeosporioides*		*C. acutatum*	
Steps	Temp (°C)	Duration (min)	Temp (°C)	Duration (min)	Temp (°C)	Duration (min)
Initial Denaturation	92	3	92	3	92	3
Denaturation	92	1	92	1	92	1
Annealing	56	1	62	1	62	1
Extension	72	1	72	1	72	1
Final Extension	72	10	72	10	72	10
Hold	4	20	4	20	4	20
No of Cycles	30		30		30	

The amplified PCR products (20µl each) to be analyzed were mixed with bromophenol blue and carefully loaded to respective sample wells using micropipette. Samples along with standard 100 bp DNA ladder were electrophoresed for about 1Hr. at 50Vcm^{-1} ensuring Ethidium bromide-stained DNA bands were observed under Gel Doc (Model No) and photographed for documentation.

Pathogenicity test

Isolated 103 fungal isolates were inoculated in healthy susceptible red chilli fruits to prove Koch's postulate of the fungus. Isolates were cultured on PDA media at 28°C for 10-15 days for sporulation in alternative 12 hours of darkness and 12 hours of light. Conidia from sporulating cultures were harvested by adding approx. 10 ml of sterilized distilled water into culture plate and was gently scrapped to dislodge the conidia. The conidial suspension was filtered aseptically through double layered muslin cloth to exclude mycelial mat and media particles. Spore count of the conidial suspension was done using haemocytometer and concentration was adjusted to get 1 X 10^6 conidia/ml. Pathogenicity test was conducted by inoculating spore suspension into the healthy fruits of susceptible chilli variety by detached fruit inoculation bio-assay as per (Kanchanaudomkan et. al. 2004). A set of same number of susceptible chillies were inoculated (as a negative control) with sterile distilled water used for preparation of conidial suspension. Separate sets of chillies were used for inoculation of different isolates to prove pathogenicity.

Inoculation Method

Chilli fruits were surface-sterilized with 0.1 % (v/v) (HgCl2) for 5 minutes and washed twice with sterile distilled water for 5 minutes each. The fruits were wiped dry with a paper towel. Fruits were inoculated with *Colletotrichum* isolate by the modified microinjection method involved pin-pricking the chilli pericarp to ≈1mm depth followed by injecting 10µl of conidial suspension (having concentration 10^6 conidia/ml) using Eppendorf repetitive micropipette in the middle portion of each chilli fruit using repetitive micropipette (Eppendorf: Multipette® plus). The inoculated fruits were incubated in plastic crates at 25°C ± 2 and ≈80% relative humidity for 10 Days. Five fruits per cultivar were taken for inoculation in each treatment. One set of negative/blank control fruits were inoculated with 10 µl of sterilized distilled water. To fulfil the Koch's postulates, the symptoms developed on the inoculated fruits were compared with original symptoms and the fungi were re-isolated from inoculated fruits following the above mention procedure.

Classification and Identification of predominant *Colletotrichum* species

Colletotrichum species was identified from collected infected chilli samples of different states, by analysing conidial morphology and molecular markers. In India mixed infection of *Colletotrichum capsici* and *Colletotrichum gloeosporioides* strains was observed. Out of 95 infected chilli sample locations *Colletotrichum capsici* was isolated and identified from 88 location samples and *Colletotrichum gloeosporioides* was isolated and identified from 15 location samples. However, based on this analysis *Colletotrichum capsici*

is the predominant *Colletotrichum* species infecting chilli in India. *Colletotrichum gloeosporioides* was identified from a smaller number of fields but it may become major threat to chilli crop in future days.

RESULTS AND DISCUSSION

Chilli Anthracnose samples collected from 95 different vulnerable regions in India were characterized by a circular, sunken zone with concentric rings of conidial masses on fruits of chilli. During sample collection, broadly two types of anthracnose lesion symptoms were observed on the fruits. First type of symptoms (Phenotype 1) observed in large number of samples showed dark black coloured colonies grown in concentric rings on chilli fruits (Figure 1A). Second type of symptoms observed in smaller numbers showing cream yellow to pinkish orange-coloured conidial masses grown in concentric rings on chilli fruits (Figure 1B). There were very few locations where infected fruits carrying both type of symptoms was present on the same field. The state wise, isolated isolates with different phenotypes are mentioned in Table 4. The phenotypic data is a representation as defined by (Than et. al. 2008; Mongkolporn et al. 2010; Liu et. al. 2016; de Silva et. al. 2019).

Morphological Characterization of Pathogen

In our study, isolation of pathogen was done from infected tissue or using blotter method (from infected seeds). Fungus isolated from infected fruit showing Anthracnose phenotype 1 (Figure 1A) has shown formation of dark black coloured lesions containing acervuli bearing setae on the PDA as well as moist filter paper (Figure 2A). On the other hand, fungus isolated from fruit showing Anthracnose phenotype 2 (Figure 1B) (with creamy yellow to pinkish orange-coloured lesions) was successfully isolated from infected chilli tissue and produced acervuli without setae on the PDA (Figure 2C).

In vitro cultural characteristics were important for differentiating among *Colletotrichum* species (Prihastuti, H. et al, 2009). Traditionally, species identification is principally based on morphology, host specialization, and mode of parasitism (Bailey et al. 1996; Cannon et al. 2008; Josep et. al 2004; Pratibha, 2009). In our study, the appearance of colony characters on PDA was observed after 10 days of sub-culturing. The mycelia of all isolated fungi formed cottony, fluffy aerial mycelial growths on PDA. The mycelial colony colour from upper side appeared to be greyish-white, while it was appeared pale orange when observed from backside (Figure 2C). *C. capsici* cultures had dense aerial mycelium, were dark brown to black or greyish felt mycelium. Tufting of mycelium was irregular, with honey-coloured or greyish conidial masses. Acervuli were formed with abundant dark setae (Figure 2B). Morphological characters of all the isolates were examined using a Leica DM6000B LED compound microscope. Conidia of *C. capsici* were hyaline, falcate with acute apex and narrow truncate base, aseptate, uninucleate, 16 - 23 × 3 - 5 μm (Figure 2D).

Morphological characters of the spores were matching the previous reports (Liu et. al. 2016.; Than et al., 2008) *C. gloeosporioides* conidia in all isolates were smooth-walled, hyaline, straight, aseptate, cylindrical with both end round, 11 to 18 μm × 3.1 - 4 μm wide (Figure 2E). Mycelial growth of associated cultures observed cottony, fluffy whitish grey mycelial growth on PDA. Microscopic observation of *C. gloeosporioides* isolates did not showed setae formation. Cultural characteristics observed in our study were in line with the earlier studies reported (Kim et. al., 2008; Prihastuti, H. et al, 2009; Ismail et.al., 2015; Liu et. al., 2016). However, conidial morphology and cultural characteristics often overlap between *C. acutatum* and *C. gloeosporioides* (Freeman and Rodriguez 1995; Freeman et al. 2000; Widodo and Hidayat, 2018), consequently, leading to confused diagnosis between *C. acutatum* or *C. gloeosporioides* (Bailey et al. 1996; Sutton 1980; 1992) caused the anthracnose symptom. For this reason, these results need to be confirmed using species-specific molecular markers to avoid misidentification of the species.

DNA Extraction:

Total 103 *Colletotrichum* isolates were subjected to DNA isolation as per method mentioned by (Dellaporta et. al. 1983). Genomic DNA was extracted from 7 days old mycelial mat grown on Potato Dextrose Broth. Proper isolation of genomic DNA and its concentration was confirmed by running on 0.8% Agarose Gel (Figure 3). Molecular confirmation of the *Colletotrichum* species was completed by amplification of 103 isolate's genomic DNA with 3 separate PCR by species-specific primers of *C. capsici*, *C. gloeosporioides and C. acutatum* (Table 1). After amplification with *C. capsici* markers (C cap-F and C cap-R) 88 samples shown expected amplicon band of 394bp (Figure 4) on separation of agarose gel and confirmed as *Colletotrichum capsici*. The results were matching PCR detection of *C. capsici* (Tapia-Tussell et al. 2008). After amplification with *Colletotrichum gloeosporioides* markers (Cg INT-F and ITS-4-R) 15 samples shown expected amplicon of 450bp (Figure 5) on separation of agarose gel confirming the presence of *Colletotrichum gloeosporioides*. (Kim et. al., 2008) also used the same primer pair for identification of *Colletotrichum gloeosporioides*. In the same manner all the DNA samples were amplified using *Colletotrichum acutatum* markers (Ca INT-2-F and ITS-4-R) but none of our sample showed expected amplicon of 490bp (Figure 6) on agarose gel confirming the absence of *Colletotrichum acutatum* in the samples.

Several molecular techniques have been developed to characterize populations of *Colletotrichum spp.*, and to identify different *Colletotrichum spp.* (Crouch et. al. 2009; Garrido et al. 2008; Johnston and Jones 1997; Lardner et al. 1999). Arbitrarily primed PCR and limited restriction digest analysis of PCR-amplified rRNA were employed to differentiate between *C. gloeosporioides* and *C. acutatum* isolates from a diverse host range

Table 4. State-wise samples collected and their phenotype

States	Total Locations	(Phenotype 1) *C. capsici*	(Phenotype 2) *C. gloeosporioides*	Total isolates
Andhra Pradesh	18	17	4	21
Madhya Pradesh	41	40	2	42
Maharashtra	21	19	4	23
Karnataka	11	11	2	13
Tamil Nadu	3	0	3	3
Punjab	1	1	0	1
Total	95	88	15	103

Figure 1. Anthracnose Fruit rot symptom observed during survey (A) Phenotype 1 (B) Phenotype 2 (C) Image from Zoom Microscope of Anthracnose Infected and Non infected Chilli seeds.

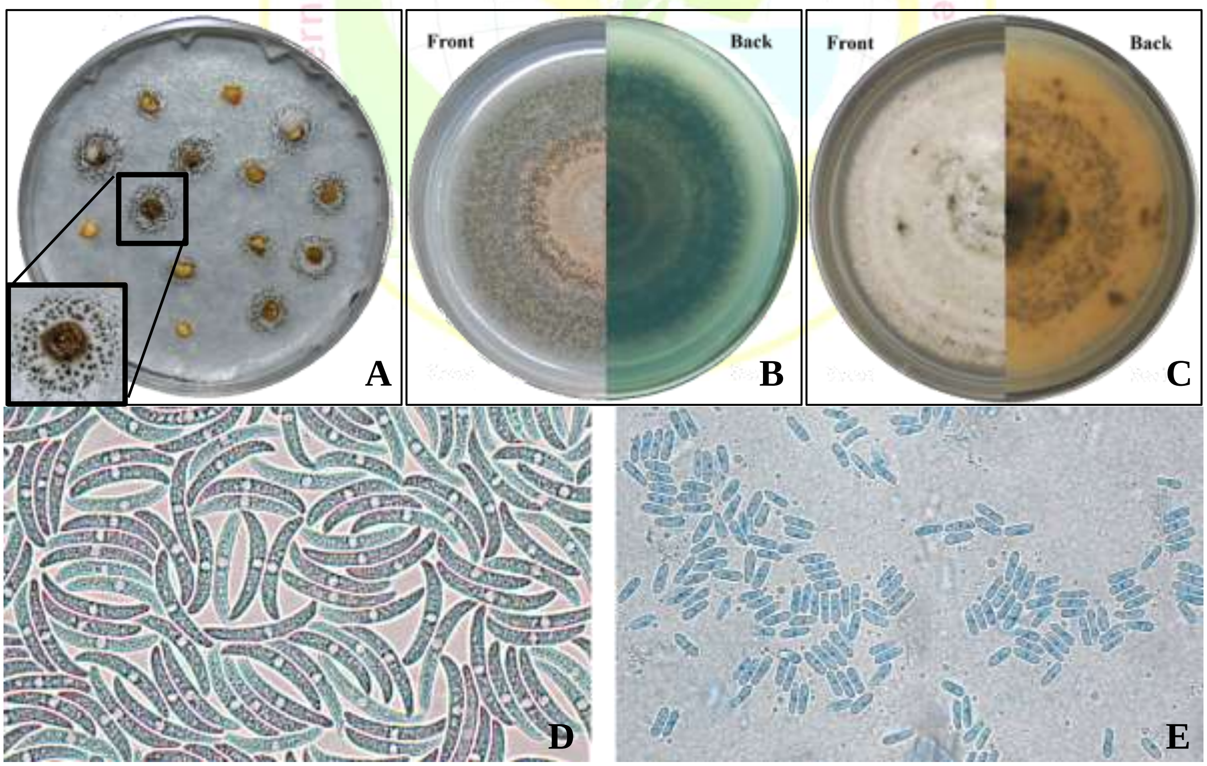

Figure 2. (A) Formation of Acervuli bearing setae on filter paper (B) Colony characteristics of *C. capsici* on PDA (C) Colony characteristics of *C. gloeosporioides* on PDA (D) *C. capsici* conidial morphology observed under microscope (E) *C. gloeosporioides* conidial morphology observed under microscope.

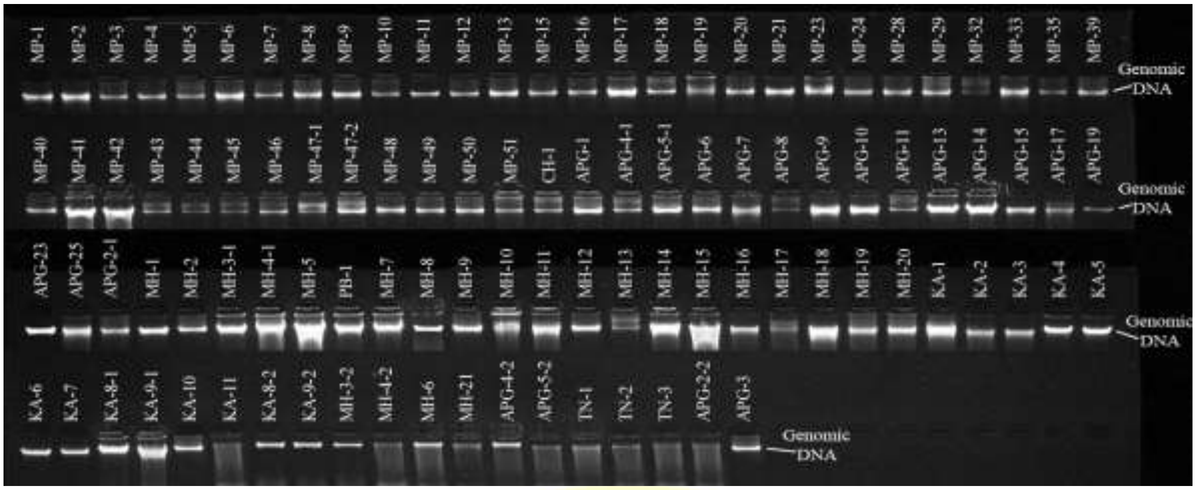

Figure 3. Genomic DNA Observed in Gel Doc after running on 0.8% Agarose Gel.

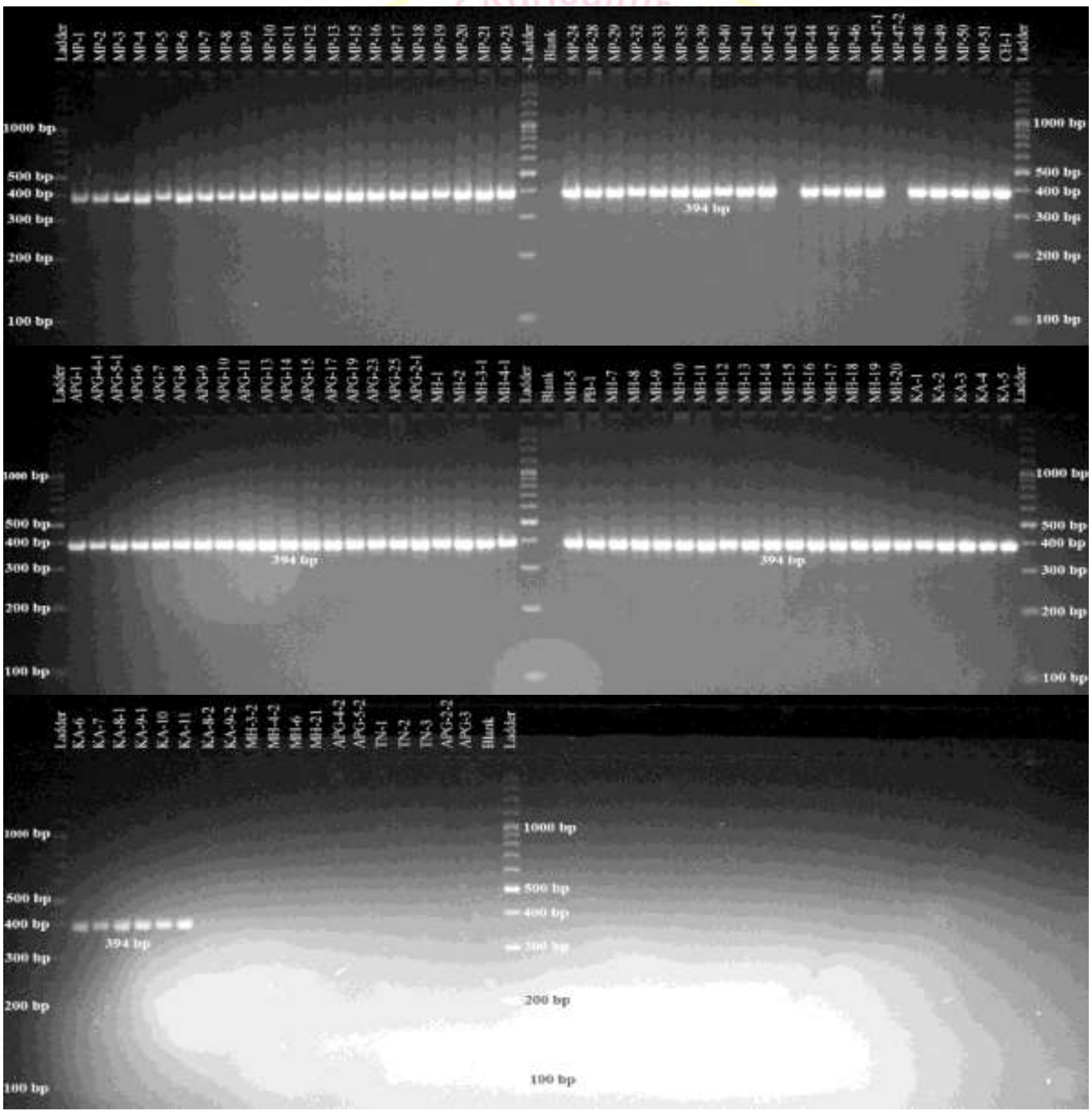

Figure 4. Results of PCR Amplification of 103 isolates with *C. capsici* species specific primer (Expected Amplicon

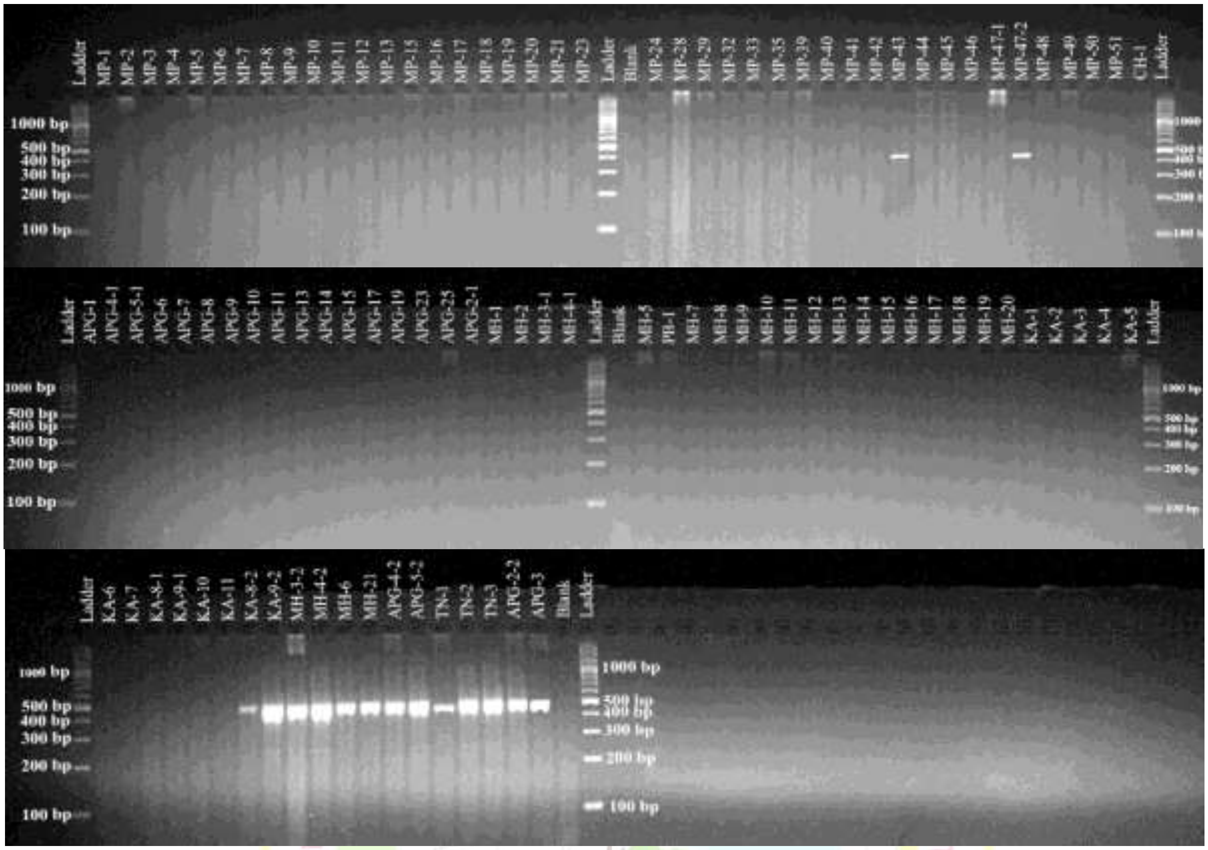

Figure 5. Results of PCR Amplification of 103 isolates with *C. gloeosporioides* species specific primer (Expected Amplicon 450bp).

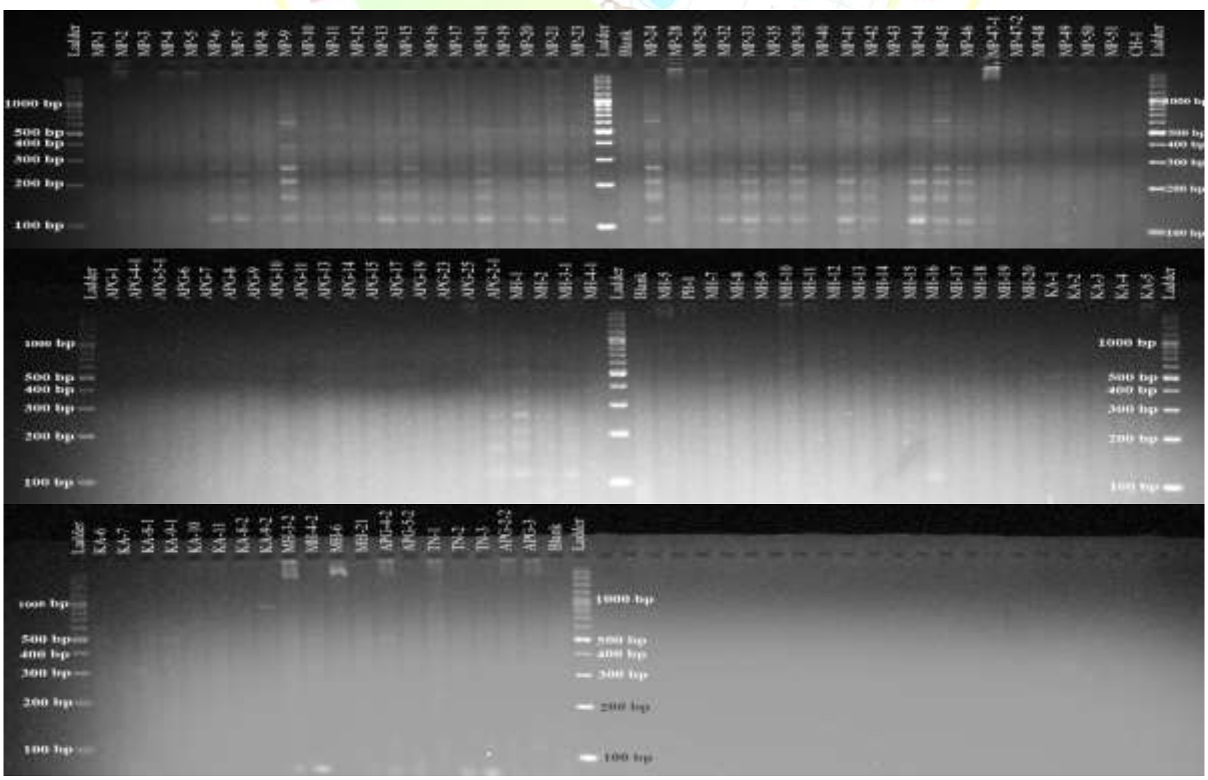

Figure 6. Results of PCR Amplification on 103 isolates with *C. acutatum* species specific primer (Expected Amplicon

Table 5. Details of disease samples collected and *Colletotrichum* species identified

Sr. No.	District	Code	*Colletotrichum sp.*	Setae
Madhya Pradesh (2021)				
1	Khandwa	MP-1	*C. capsici*	Present
2		MP-50	*C. capsici*	Present
3		MP-2	*C. capsici*	Present
4		MP-3	*C. capsici*	Present
5		MP-4	*C. capsici*	Present
6		MP-5	*C. capsici*	Present
7		MP-6	*C. capsici*	Present
8		MP-7	*C. capsici*	Present
9		MP-8	*C. capsici*	Present
10		MP-9	*C. capsici*	Present
11		MP-10	*C. capsici*	Present
12		MP-11	*C. capsici*	Present
13		MP-12	*C. capsici*	Present
14	Khargone	MP-13	*C. capsici*	Present
15		MP-15	*C. capsici*	Present
16		MP-16	*C. capsici*	Present
17		MP-17	*C. capsici*	Present
18		MP-18	*C. capsici*	Present
19		MP-19	*C. capsici*	Present
20		MP-20	*C. capsici*	Present
21		MP-21	*C. capsici*	Present
22		MP-23	*C. capsici*	Present
23	Manawar	MP-24	*C. capsici*	Present
24		MP-28	*C. capsici*	Present
25		MP-29	*C. capsici*	Present
26		MP-32	*C. capsici*	Present
27		MP-33	*C. capsici*	Present
28		MP-35	*C. capsici*	Present
29		MP-39	*C. capsici*	Present
30		MP-40	*C. capsici*	Present
31		MP-48	*C. capsici*	Present
32		MP-49	*C. capsici*	Present
33	Dhar	MP-41	*C. capsici*	Present
34		MP-42	*C. capsici*	Present
35		MP-43	*C. gloeosporioides*	Absent
36		MP-44	*C. capsici*	Present
37		MP-45	*C. capsici*	Present
38		MP-46	*C. capsici*	Present
39		MP-47-1	*C. capsici*	Present
40		MP-47-2	*C. gloeosporioides*	Absent
41	Ratlam	MP-51	*C. capsici*	Present
Chhattisgarh (2021)				
42	Bilaspur	CH-1	*C. capsici*	Present
Andhra Pradesh (2020)				
43	Guntur	APG-1	*C. capsici*	Present
44		APG-2-1	*C. capsici*	Present
45		APG-2-2	*C. gloeosporioides*	Present
46		APG-3	*C. gloeosporioides*	Absent
47		APG-4-1	*C. capsici*	Present
48		APG-4-2	*C. gloeosporioides*	Absent
49		APG-5-1	*C. capsici*	Present
50		APG-5-2	*C. gloeosporioides*	Absent
51		APG-6	*C. capsici*	Present
52		APG-7	*C. capsici*	Present
53		APG-8	*C. capsici*	Present
54		APG-9	*C. capsici*	Present
55		APG-10	*C. capsici*	Present
56	Prakasam	APG-11	*C. capsici*	Present
57		APG-13	*C. capsici*	Present
58		APG-14	*C. capsici*	Present
59		APG-15	*C. capsici*	Present
60	Kurnool	APG-17	*C. capsici*	Present
61		APG-19	*C. capsici*	Present
62		APG-23	*C. capsici*	Present
63		APG-25	*C. capsici*	Present
Karnataka (2020)				
64	Bellari	KA-1	*C. capsici*	Present
65		KA-2	*C. capsici*	Present
66		KA-3	*C. capsici*	Present
67		KA-4	*C. capsici*	Present
68		KA-5	*C. capsici*	Present
69		KA-6	*C. capsici*	Present
70		KA-7	*C. capsici*	Present
71		KA-8-1	*C. capsici*	Present
72		KA-8-2	*C. gloeosporioides*	Absent
73		KA-9-1	*C. capsici*	Present
74		KA-9-2	*C. gloeosporioides*	Absent
75		KA-10	*C. capsici*	Present
76		KA-11	*C. capsici*	Present
Tamil Nadu (2019-2020)				
77	Trichi	TN-1	*C. gloeosporioides*	Absent
78		TN-2	*C. gloeosporioides*	Absent
79		TN-3	*C. gloeosporioides*	Absent
Maharashtra (2017-2021)				
80	Nagpur	MH-1	*C. capsici*	Present
81		MH-2	*C. capsici*	Present
82		MH-3-1	*C. capsici*	Present
83		MH-3-2	*C. gloeosporioides*	Absent
84		MH-4-1	*C. capsici*	Present
85		MH-4-2	*C. gloeosporioides*	Absent
86		MH-5	*C. capsici*	Present
87		MH-6	*C. gloeosporioides*	Absent
88		MH-8	*C. capsici*	Present
89		MH-10	*C. capsici*	Present
90		MH-11	*C. capsici*	Present
91		MH-12	*C. capsici*	Present

92		MH-13	*C. capsici*	Present
93		MH-14	*C. capsici*	Present
94		MH-15	*C. capsici*	Present
95		MH-16	*C. capsici*	Present
96		MH-17	*C. capsici*	Present
97		MH-18	*C. capsici*	Present
98		MH-19	*C. capsici*	Present
99		MH-20	*C. capsici*	Present
100	Yavatmal	MH-21	*C. gloeosporioides*	Absent
101	Wardha	MH-7	*C. capsici*	Present
102	Latur	MH-9	*C. capsici*	Present
Punjab (2021)				
103	Fazilka	PB-1	*C. capsici*	Present

Species-specific primers have also been designed based on dissimilarities in the sequence of the internal transcribe spacer (ITS) regions of representative isolates of *Colletotrichum*. This approach has been demonstrated to be a reliable technique to identify and differentiate *C. acutatum* from *C. gloeosporioides* (Harp et al. 2008; Sreenivasaprasad et al. 1992; 1994; Kamle et. al. 2013; Widodo and Hidayat, 2018).

Pathogenicity of identified *Colletotrichum* species.

After incubation period for 10 days, *Colletotrichum* symptoms were produced by all the isolates. Red chilli sets inoculated with *C. capsici* isolates has developed sunken lesions bearing black coloured setae and acervuli with greyish coloured conidial masses developed in concentric rings. Red Chilli sets inoculated with *C. gloeosporioides* has developed sunken lesions with pinkish to orange coloured spore masses in concentric rings around point of inoculation. The fungi were reisolated and we received satisfactory results to prove Koch's postulates.

Identification of predominant species

In our experiment, infected chilli samples were collected from 95 locations and successfully isolated 103 *Colletotrichum* isolates. *Colletotrichum capsici* was identified and confirmed from 88 location samples while *Colletotrichum gloeosporioides* was identified and confirmed from 15 location samples. Based on current study, the predominant species was *Colletotrichum capsici* in India as identified and confirmed with species specific markers. Sampling details along with identified *Colletotrichum* species is mentioned in Table 5.

The present findings agree with the earlier reports of (Patidar and Tomar, 2022) from Sehore district of Madhya Pradesh and (Harshitha et. al. 2022) from northern part of Karnataka. Additionally, *Colletotrichum acutatum* was also spotted at few locations in North Karnataka (Harshitha et. al. 2022). *C. capsici* and *C. gloeosporioides* were the 2 predominant species in Southern India (Rao et al., 2007). *C. capsici* was prominent in Karnataka, Tamil Nadu and Maharashtra (Rao et al., 2007), Himanchal Pradesh (Sharma et al., 2005), Andhra Pradesh (Rao et al., 2007; Pratibha, 2009; Nanda, 2011) and in Arunachal Pradesh (Selvakumar, 2007). (Anamika et. al., 2014) reported *C. capsici* and *C. gloeosporioides* causing serious problem for chilli cultivation in Fiji. Similarly isolates collected from chili producing areas of Indonesia, Malaysia, Sri Lanka, Thailand, and Taiwan showed predominance of *Colletotrichum capsici* (De silva et. al. 2019). Reports of (Liu et. al. 2016) confirming predominance of *C. capsici* infecting chilli from Sichuan Province, China. However, *C. acutatum* has been reported to be predominant species followed by *C. capsici* and *C. gloeosporioides* particularly in Indonesia (Widodo and Hidayat, 2018) and in Korea (Kim et. al. 2008).

In our study we did not find *C. acutatum* while (Harshitha et. al. 2022) reported it from some locations in North Karnataka. We have collected infected samples from Karnataka region in Kharif 2020 while (Harshitha et. al. 2022) has collected samples in Kharif 2021. It is possible that this species was missed unfortunately during collection. In Kharif 2021 we have received some reports (data unpublished) of outbreak of *C. acutatum* from Karnataka particularly infected chilli on green fruit stage but unfortunately, we were unable to collect samples and include in this study.

Researchers from other countries have already mapped their regional *Colletotrichum* isolates. India contributing very large agricultural area specifically growing chilli and recently anthracnose creating havoc to chilli growers due to climate change and favorable disease conditions. Most of the Indian studies published recently emphasizing on small geographical area and that too in different years. This misleads the by and large scenario of the current anthracnose disease incidence. This study was specifically carried out with Indian *Colletotrichum* isolates which demonstrate the current tentative/approximate contribution of different Anthracnose causing *Colletotrichum* species. To identify the resistant/immune germplasm for Anthracnose, the geographical mapping of *Colletotrichum* species is of prime importance.

CONCLUSION

Anthracnose infection mainly affects chilli at red fruit stage. Morphological characterization of collected samples from the surveyed region revealed that *Colletotrichum capsici* and *C. gloeosporioides* were the major species infecting chilli while *Colletotrichum capsici* was the predominant species. As *C. capsici* is predominant species causing Anthracnose, we need anthracnose resistant source at least against *C. capsici*. Resistant source against both C, capsici and *C. gloeosporioides* will be a boon for breeders to strengthen disease resistance.

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Research Article

Maize response to phosphorus and sulfur application on calcareous chernozem in Serbia

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ABSTRACT
Field studies were conducted on carbonate chernozem in *Vojvodina Province* of Serbia during two seasons of maize growing to adjust nutrient management practices when fertilizers are broadcasted and incorporated into the soil before sowing. The experimental scheme included six fertilization treatments: T_1 (zero fertilizer control), T_2 ($N_{156}P_{64}K_{64}$, farmer fertilizer practice), T_3 ($N_{100}P_{60}K_{60}$), T_4 ($N_{100}P_{60}K_{60}S_{36}$), T_5 ($N_{100}P_{80}K_{60}$), and T_6 ($N_{100}P_{80}K_{60}S_{48}$). Nitrogen application practice was found to be excessive, while phosphorus application practice was found to be insufficient. Phosphorus application rate of 80 kg P_2O_5 ha^{-1} was found to be rational when the soil test for phosphorus was very low or low. Sulfur (S) application improved grain yield in higher yield conditions, whereas soil containing 3.9–4.0% of organic matter (OM) could meet crop S requirements in lower yield conditions of 5 t ha^{-1} and below. It is assumed that S application to maize in *the southern Pannonian Plain in Serbia* may be limited to 36 kg S ha^{-1}.
Keywords: maize, grain yield, phosphorus, sulfur.

INTRODUCTION

Nutrient removal per 1 ton of maize grain averages 12 kg N, 6.3 kg P_2O_5, 4.5 kg K_2O, and 1.4 kg S (IPNI, 2016). More than half of total phosphorus (P) uptake by maize plants occurs after the tassel/first reproductive (VT/R1) stages, and S accumulation is greater during grain-filling stages, with more than half of sulphur (S) uptake occurring after the VT/R1 stages (Bender *et al*., 2013). Such dynamics of nutrient demand suggests that season-long supply of P and S is critical for maize nutrition.

Marginal purpling of maize leaves is a well-known symptom of P deficiency (Sharma and Kumar, 2011). However, P deficiency can slow plant growth and delay maturity without causing purpling; some maize hybrids show no signs of purpling even when severely deficient in P. Purpling may also be caused by a restriction of root growth, indicating that the plant is under stress, such as freezing stress (Bruulsema, 2016).

Phosphate sorption and precipitation are strongly favored in calcareous soils because of high concentrations of calcium carbonate ($CaCO_3$) increasing the soil's P buffer capacity, sorption strength, and precipitation reactions forming stable Ca phosphates (Brownrigg *et al*., 2022). It was hypothesized that after each P fertilizer application, the soil buffering capacity decreases, as does the soil's proclivity to continue reacting with P, resulting in more P in soil solution and, consequently, plants requiring less P (Barrow *et al*., 2018). Every phosphate fertilizer application thus increases the effectiveness of subsequent applications (Barrow *et al*., 2021). Understanding *phosphate* sorption and desorption in *soils* helps to rationalize P fertilizer use and avoid overfertilization, which causes eutrophication of surface waters. Maintaining or improving agricultural productivity while conserving and enriching the biodiversity is critical to the global provision of ecosystem services (Guignard *et al*., 2017).

For maize fields with very low soil test P values, it is typically recommended to broadcast a P rate before sowing and place the remainder of P fertilizer in bands at sowing. If the soil test P value is low or medium, P fertilizer can be applied via broadcasting or banding. If the P soil test value is high, banding is suggested (Kaiser *et al*., 2022), as broadcasting P fertilizer has a low chance of increasing maize yields when the soil test P value is high. Maize grain yield after broadcast and deep-band P fertilizer placement has been shown to be comparable across experimental years with strip-till operation, while the improved early growth and P uptake after deep-band placement may provide benefits at the field scale (Preston *et al*., 2019).

Sulfur nutrition is critical for plant growth and development, and this secondary macronutrient is increasingly being used in many crops. Plants absorb sulfate and convert it to essential amino acids, where S

participates in a variety of metabolic functions, including protein synthesis (Norton *et al*., 2013). In young maize plants, sulfur deficiency may manifest as a general yellowing of the foliage (Sharma and Kumar, 2011). Because S is not easily translocated in the plant, S deficiency causes more yellowing of the younger leaves than N deficiency.

The frequency of maize responses to S fertilization can be quite high. Sulfur is best obtained from fertilizers containing sulfate (SO_4^{2-}) or thiosulfate ($S_2O_3^{2-}$). Broadcast application of 28 kg S ha^{-1} or placement of 13.5 kg S ha^{-1} in a band near the maize seed at sowing has proven to be satisfactory in most production scenarios (Rehm and Clapp, 2008). In S application rate studies conducted in Iowa, the U.S., 62% of the sites showed a significant yield increase due to applied S fertilizer: 72% of sites with loam, silt loam, fine sandy loam, loamy fine sand, and sandy loam textural classes; and 14% of sites with silty clay loam or clay loam textural classes (Sawyer *et al.*, 2011). The economic optimum S rate in these studies was 18 kg S/ha for fine-textured soils and 26 kg S/ha for coarse-textured soils. Maize yield increased with 11 kg S ha^{-1} rate in two of ten locations in two states in the U.S., and yield was unrelated to both soil S and plant tissue S concentration (Kaur *et al*., 2019). It was assumed that S from subsoil plus mineralized S from soil organic matter could have met crop S demand at most locations. A controlled-climate chamber study suggests that S fertilizer application may benefit early season maize growth, but the response may be site-specific (Kovar, 2021).

An increase in S application to many crops coincides with a decrease in atmospheric S deposition as air quality improves. For example, an increase in S fertilizer use in the U.S. Midwest has outpaced the relative rate of change in other nutrient application, such as N, P, and K (Hinckley and Driscoll, 2022). It is therefore suggested that rational S fertilizer recommendations are urgently needed in order to maintain crop yields while minimizing the environmental consequences of excess S levels.

The ability of soil S tests to predict crop response to applied S has been inconsistent (Flis and Jones, 2020). Because S availability to plants is partially dependent on soil organic matter (OM) mineralization, the extractable SO_4-S concentration in top soil is unreliable for indicating potential S deficiency or the need for S application. Soil organic matter has a slightly better association with yield response, but does not clearly distinguish between responsive and non-responsive sites for the same reasons (Sawyer *et al.*, 2011). Sulfur mineralization assessment can be used to predict S availability to maize in the field (Carciochi *et al*., 2018). Sulfur applied together with P influences the behavior of the applied P in the soil. Eight weeks after MAP application in the seed-row together with $CaSO_4$, the proportion of phosphate adsorbed on the surface of soil minerals increased, while the proportion of brushite ($CaHPO_4 \cdot 2H_2O$) decreased in calcareous soil, compared to MAP alone (Kar *et al*., 2016). Sulfate S may contribute to increased P solubility in calcareous soils through complexation of Ca^{2+} with SO_4^{2-} (Brownrigg *et al*., 2022).

The objective of this study was to adjust nutrient management practices for maize on calcareous chernozem. Field experiments including six fertilization treatments were conducted based on the following assumptions: high P rates are required when available soil P levels are low; balanced P and S fertilization improves grain yield and economic return; crop response to S depends on yield potential.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in an intensive cropping system in a farmer's field in Ruma municipality, *Vojvodina Province,* Serbia. The experimental site is located in Syrmia, in *the southern Pannonian Plain,* between the Danube and Sava rivers. It is a *temperate continental climate* region *where farmers primarily grow* field crops such as maize, oilseeds, sugar beet, and tobacco on chernozem soils formed on loess parent material.

Climate and soil

The first experimental season in 2020 had favorable climatic conditions for maize. The period from November 2019 to October 2020 saw a 15% increase in precipitation over the long-term average, but there was a precipitation deficit in January, March, and April. Maize was sown in soil with low moisture reserves, and 94% of the plants emerged 16 days after sowing. Rainfall totaled 374 mm from sowing on April 14 to harvesting on November 5, 2020, which is sufficient for a good crop yield. The temperature conditions were favorable during the first vegetative season.

A severe lack of precipitation and higher temperatures characterized the second growing season. From, precipitation was 45% lower than the long-term average. Only 197 mm of rain fell during the vegetative season, which lasted from April 15 to October 12, 2022.

Table 1. Initial soil characteristics (0 to 30 cm) at the experimental sites.

Parameters		2020	2022
OM (%)		3.88	4.02
pH (H_2O)		8.10	7.52
CEC (mmol$_c$ 100 g^{-1})		31.2	29.6
NH_4-N	mg kg^{-1}	7.1	3.6
NO_3-N	mg kg^{-1}	10.2	6.2
Olsen P	mg kg^{-1}	13.6	9.3
Available K (AL method)	mg kg^{-1}	174	206
Exchangeable Ca	mg kg^{-1}	422	568
Exchangeable Mg	mg kg^{-1}	36.2	45.3
Exchangeable Na	mg kg^{-1}	34.6	21.0
Available S (*1 M KCl* extractable)	mg kg^{-1}	1.2	1.1

The soil has a diagnostic mollic horizon and is classified as chernozem according to WRB (2014). According to the national soil classification (Škorić *et al*., 1985), the soil is a medium deep carbonate chernozem formed on loess and loess-like sediments. The soil textural class is clay loam, with the following particle size distribution in 0–30 cm layer: 28% sand, 34% silt, and 38% clay. The soil had relatively low OM content (3.9–4.0%), a high cation exchange capacity (CEC) (30–31 $mmol_c$ 100 g^{-1}), and reaction ranging from slightly to moderately alkaline (pH=7.5–8.1) (Table 1). Mineral N and available P were both in the very low to low ranges; available K was in the medium to high ranges; and available S was low. The soil in the experimental site was not salinized, and the exchangeable sodium percentage (ESP) ranged from 0.3% to 0.5%.

Experimental design and treatment

The experimental scheme included six fertilization treatments (Table 2). Treatment T_1 was a zero fertilizer (control), and treatment T_2 ($N_{156}P_{64}K_{64}$) corresponded to farmer fertilization practice (FFP) in the region. In treatment T_3 ($N_{100}P_{60}K_{60}$), N rate was 36% lower than in T_2, assuming the farmer's practice overestimates N demand. Treatment T_4 ($N_{100}P_{60}K_{60}S_{36}$) had S rate of 36 kg S ha^{-1} in a sulfate form, from a complex NPS fertilizer. In treatment T_5 ($N_{100}P_{80}K_{60}$), P rate was increased to 80 kg P_2O_5 ha^{-1} considering low and very low levels of available soil P. Treatment T_6 ($N_{100}P_{80}K_{60}S_{48}$) also had a higher P rate of 80 kg P_2O_5 ha^{-1} and S rate of 48 kg S ha^{-1} from an NPS fertilizer. Urea was applied in all treatments to obtain the required N rate. Muriate of potash (MOP) was used as a K source in treatments 3–6. Mineral fertilizers were spring broadcasted prior to preplant cultivation.

Maize hybrid P0164 (FAO 420) was grown after sunflower during the first experimental season and after winter wheat during the second experimental season, with a seed rate of 75,000 seeds ha^{-1}. Soil tillage operations included autumn plowing at a depth of 30 cm, disk tillage at a depth of 15 cm in December, and pre-sowing cultivation at a depth of 10 cm. In both seasons, crop protection included pre-emergence (terbuthylazine + metolachlor) and post-emergence herbicides (mesotrione + nicosulfuron).

Plot sizes ranged from 130 to 800 m^2 in the first and second seasons, respectively, according to a systematic experimental design with four replications. Tukey's Honest Significant Difference (HSD) test was used to assess the significance of differences between pairs of group means.

RESULTS AND DISCUSSION

Growth parameters

The number of plants emerged per hectare was measured at BBCH (plant phenological stage) 10 (Table 3). Fertilizer application had no significant effect on plant stand measured at this stage. All nutrient management systems increased plant height measured at BBCH 99 compared to a control treatment T_1, but there were no significant differences between fertilizer treatments.

Table 2. Experimental treatments.

Treatment		Fertilizer	Rate (kg ha^{-1})
T_1	Control	-	-
T_2	$N_{156}P_{64}K_{64}$ (FFP*)	NPK 16-16-16	400
		Urea	200
T_3	$N_{100}P_{60}K_{60}$	Apaviva® NP 12-52	115
		Urea	190
		MOP	100
T_4	$N_{100}P_{60}K_{60}S_{36}$	Apaviva® NP(S) 16-20(12)	300
		Urea	110
		MOP	100
T_5	$N_{100}P_{80}K_{60}$	Apaviva® NP 12-52	153
		Urea	180
		MOP	100
T_6	$N_{100}P_{80}K_{60}S_{48}$	Apaviva® NP(S) 16-20(12)	400
		Urea	80
		MOP	100
*Farmer fertilization practice in Vojvodina region (Serbia).			

Yield components

Fertilizer management practices had no effect on ear quantity per hectare during both seasons (Table 4), as evidenced by the absence of an effect on plant population. Ear length (EL), an important component of grain yield, was only measured in the second season. Nutrient management systems studied in the last two treatments (T_5 and T_6) provided a significant increase in EL compared to T_1. In the first year, thousand kernel weight (TKW) was significantly improved in treatments T_4, T_5, and T_6 compared to T_1. Only the last treatment, T_6, showed a positive effect of fertilization on TKW in 2022.

Grain yield and quality

Grain yield increased by 16% and 19% in the first and second seasons, respectively, when FFP was used in T_2 versus a zero-fertilizer treatment T_1 (Table 5). The N rate of 156 kg ha^{-1} typically applied by farmers appears to be excessive under rainfed conditions, given that in both years, nearly the same yield was obtained in treatment T_3 with a much lower N rate of 100 kg ha^{-1}.

Treatment T_5 with the highest P rate of 80 kg P_2O_5 ha^{-1} produced the highest grain yield of 11.03 t ha^{-1} in 2020 and 5.10 t ha^{-1} in 2022. Site-specific management for primary macronutrients increased grain productivity by 15% in the favorable first year and by up to 20% in the drought-affected second year, when compared to T_2 that corresponded to FFP. When comparing treatments T_3 and T_5, very low and low ranges of available soil P found in the study area explain a noticeable maize response to a higher P rate with grain yield increase by 15–18%.

Sulfur addition at a lower rate improved maize grain yield. When comparing treatments T_3 and T_4, S application at 36 kg S ha^{-1} increased grain yield by 7% in the first season. However, the positive effect of S application on crop productivity was not significant in

the second season, which was characterized by a lack of precipitation. Sulfur mineralization in carbonate chernozem containing 3.9-4.0% OM was presumably sufficient to meet maize S requirements, considering that grain yield was more than two times lower in a drier year (5 t ha^{-1} and below).

Table 3. Effect of P and S application on maize growth parameters.

Treatment		Plant population at BBCH 10		Plant height (cm)	
		2020	2022	2020	2022
T_1	Control	69,683	71,076	252.4	187.0
T_2	$N_{156}P_{64}K_{64}$ (FFP)	69,825	71,221	273.0	195.5
T_3	$N_{100}P_{60}K_{60}$	69,801	71,197	270.0	196.5
T_4	$N_{100}P_{60}K_{60}S_{36}$	70,015	71,415	269.6	207.1
T_5	$N_{100}P_{80}K_{60}$	70,110	71,512	269.4	199.3
T_6	$N_{100}P_{80}K_{60}S_{48}$	70,500	71,909	267.7	203.1
HSD (p=0.05)		NS	NS	5.4	13.2

Table 4. Effect of P and S application on maize yield components.

Treatment		Ear quantity per ha		EL (cm)	TKW (g)	
		2020	2022	2022	2020	2022
T_1	Control	67,592	64,125	14.5	305.0	214.6
T_2	$N_{156}P_{64}K_{64}$ (FFP)	68,429	65,676	15.3	350.8	222.8
T_3	$N_{100}P_{60}K_{60}$	68,508	65,750	15.0	345.3	231.3
T_4	$N_{100}P_{60}K_{60}S_{36}$	68,615	66,675	16.6	371.0	241.6
T_5	$N_{100}P_{80}K_{60}$	68,475	67,995	16.7	365.3	249.9
T_6	$N_{100}P_{80}K_{60}S_{48}$	69,090	65,800	16.8	365.3	239.9
HSD (p=0.05)		NS	NS	2.2	6.1	14.8

Table 5. Effect of P and S application on maize grain yield and quality.

Treatment		Grain yield, t ha^{-1}		Starch, %		Protein, %	
		2020	2022	2020	2022	2020	2022
T_1	Control	8.29	3.56	77.03	77.53	5.98	7.26
T_2	$N_{156}P_{64}K_{64}$ (FFP)	9.63	4.25	75.62	74.75	6.93	7.83
T_3	$N_{100}P_{60}K_{60}$	9.60	4.33	75.91	75.34	7.46	7.44
T_4	$N_{100}P_{60}K_{60}S_{36}$	10.30	4.47	75.78	74.19	6.56	6.96
T_5	$N_{100}P_{80}K_{60}$	11.03	5.10	76.17	76.69	7.10	7.05
T_6	$N_{100}P_{80}K_{60}S_{48}$	10.72	4.72	75.22	76.81	7.23	6.94
HSD (p=0.05)		0.38	0.19	1.32	1.03	1.40	0.83

Sulfur application at a higher rate of 48 kg S ha^{-1} was ineffective during both seasons, and such a rate of S even reduced grain yield by 7% in the second year with a lack of precipitation. *Maize* is known to be moderately sensitive to *salt* stress (Farooq *et al*., 2015), but we assume that factors other than salt stress were at work because the total amount of nutrients applied in treatments T_2 and T_6 was nearly similar. Thus, S fertilization of maize should not exceed 36 kg S ha^{-1} in the study area. Kaur *et al*. (2019) also observed a significant decrease in maize grain yield when the S rate was increased from 33 to 44 kg S ha^{-1} in four of ten locations in two states in the U.S.

There was no clear relationship between nutrient management and protein content in maize grain (Table 5). Optimal nutrition with macronutrients in treatment T_5 with a higher P rate of 80 kg P_2O_5 ha^{-1} resulted in a higher starch content in grain during both seasons, when compared to treatment T_2 that corresponded to FFP.

CONCLUSION

Optimized nutrient management improved maize productivity by 15–20% and increased starch content in grain at the experimental site in *Vojvodina Province* of Serbia. Phosphorus application rate of 80 kg P_2O_5 ha^{-1} was found to be rational when the soil test P values were in the very low and low ranges. Sulfur application rate of 36 kg S ha^{-1} improved grain yield in higher yield conditions, and it is assumed that S application to maize under these conditions can be limited to the above-mentioned rate. Carbonate chernozem containing 3.9–4.0% OM is assumed to meet crop S requirements in lower yield conditions of 5 t ha^{-1} and below.

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Review Article

Scenario of climate change impact on insect pests in India

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ABSTRACT
The climate change has been intensified the risk of climate dependent crop production. Increase in temperature can reduce crop duration, increase crop respiration rates, alter photosynthesis process and affect the survival and proliferation of pest populations. The importance of climate and weather events to the distribution of insects and their population dynamics has long been recognized. Insects are poikilothermic in nature and are directly under the control of temperature for their growth. The duration of insect life cycle is altered under increased temperature and elevated carbon dioxide concentrations resulting in variable number of generations per year. The elevated carbon dioxide concentrations are mediated through enhanced photosynthesis in plants for phytophagous insects' growth and development. Several insect pests, that were important in the past or the minor pests are likely to become more devastating with global warming and climate change. Insect pests cause an estimated annual loss of 13.6% globally and 23.3% in India. Losses due to insect pests are likely to increase as a result of change in crop diversity and climate change. An increase of 0.4ºC average surface temperature over past century in India has led to crop insect pests losses increase from 3.0% during the pre-green revolution period to 50% during the post-green revolution period. The changes of insect pests losses has been increased up to 32%. Considerable knowledge is available on the effects of weather and climatic events on insect pests in India. But concerned to the impact of climate change on insect pests studies are in lag phase. A major portion of the cultivated areas of India covered under rainfed. The rainfed agriculture is directly reciprocal to the climate. So, any changes in the state of climate may cause crop failure due to biotic and abiotic stresses of climatic vagaries. Therefore, detailed study of the climate change scenario, its impact on insect pest management and formulation of coping strategies are of paramount importance to reduce the risk of crop failure. This paper attempt to analyse the review of reported studies on the scenario of climate change impact on insect pests in India to reduce the risk of strategy for effective insect pest management.
Keywords: Climate change, Insect pests, Impact, Scenario, India.

INTRODUCTION

The prominent cause of climate change is the man induced global warming due to emission of greenhouse gases in the atmosphere. The global average surface temperature has increased by approximately 0.6ºC over the past century and further it will be increased by 1.4–5.8ºC over the end of 21 century. It has manifested in terms of events like melting glaciers, rising sea levels, extreme weathers and floods. The impact of climate change affects the natural resources like, land, water and forests. These could lead to impacts on fresh water availability, oceanic acidification, food production, flooding of coastal areas and increased burden of vector borne and water borne diseases associated with extreme weather events. The consistent impact of climate change may threaten livelihood activities, which are mostly based on agriculture providing food security. Climate change has been posed a significant threat to agriculture. Climate is the primary determinant of agricultural productivity. The climate change has been intensified the risk of climate dependent crop production. Increase in temperature can reduce crop duration, increase crop respiration rates, alter photosynthesis process and affect the survival and proliferation of pest populations. (NAPCC, 2008; Kannan, 2009; Dhaliwal *et al*., 2011; NATCOM, 2012; Ninan and Bedamatta, 2012; Adhinarayanan, 2013; Rattani, 2018; IPCC, 2022).

The importance of climate and weather events to the distribution of insects and their population dynamics has long been recognized. Insects are poikilothermic in nature and are directly under the control of temperature for their growth. The duration of insect life cycle is altered under increased temperature and elevated carbon dioxide concentrations resulting in variable number of generations per year. The elevated carbon dioxide concentrations are mediated through enhanced photosynthesis in plants for phytophagous insects' growth and development. So, any changes in the state of climate may cause crop failure due to biotic and abiotic

stresses of climatic vagaries. Several insect pests, that were important in the past or the minor pests are likely to become more devastating with global warming and climate change. Overwintering of insect pests will increase as a result of climate change producing larger spring population as a base for a build-up in numbers in the following seasons. Many insect species, that will move to newer areas as invasive pests due to climate change. The legume pod borers (*Helecoverpa armigera* and *Maruca vitrata)* presently confined to tropical climates in Asia, Africa and Latin America are most likely to move to northern Europe and North America over the next 50 years as a result of global warming and climate change is now become the classical example. (Bale *et al*., 2002; Benedict, 2003; Rao *et al*., 2010; Sharma, 2014; Sharma, 2016; IPCC, 2022).

India is a vast country occupying 2.4% world geographical area sharing 16.2% of the global human population and 15% of the global livestock population. More than 60% of its population living in rural India. Agriculture is the backbone of Indian economy, that is the crucial for food and livelihood security in India. It mostly depends on onset of monsoon and its further behaviour. The cultivated fields are diverse, heterogenous and unorganised, and almost 60% are rainfed. The vulnerability of agricultural production to climate change depends not only on the physiological response of the affected plant, but also on the ability of the affected socio-economic systems of production to cope with changes in yield, as well as with changes in the frequency of droughts or floods. This scenario is more challenging, because more than 80% Indian farmers are small and marginal with poor coping capacity. Food production in India is sensitive to climate changes such as variability in monsoon rainfall and temperature changes within a season. Small changes in temperature and rainfall have significant effects on the quality of fruits, vegetables, tea, coffee, aromatic and medicinal plants, and basmati rice. An increase of 1-4 ºC, the grain yield reduced on average by 10% for each degree of temperature increased and annual wheat production could plunge by 4-5 million tons with every 1ºC rise in the temperature have been predicted in India by the end of 21 century. It has been also predicted that, 10-40% losses in crop production in India with increase in temperature 3 to 5ºC by the end of 21 century. The loss in net revenue at the farm level is estimated to range between 9% to 25% for a temperature rise of 2ºC to 3.5ºC. Insect pests cause an estimated annual loss of 13.6% globally and 23.3% in India. These crop losses due to insect pests are likely to increase as a result of changes in crop diversity and impact of climate change. (Kumar and Parikh, 2001; Benedict, 2003; Dhaliwal *et al*., 2004; NAPCC, 2008; Kumar, 2010; Ninan and Bedamatta, 2012; Ranuzzi and Srivastava, 2012; Mahato, 2014; Rao *et al*., 2019; Vanaja, 2019; Rao *et al*., 2022).

A major portion of the cultivated areas of India covered under rainfed. The rainfed agriculture is directly reciprocal to the climate. Therefore, detailed study of the climate change scenario on the basis of long-term historic weather data, its impact on yield and formulation of coping strategy are of paramount importance to reduce the risk of crop failure. Considerable knowledge is available on the effects of weather and climatic events on insect pests growth and development in India. But concerned to the impact of climate change on insect pests and their management studies are under lag phase. This paper attempt to analyse the review of reported studies on the scenario of climate change impact on insect pests and their management in India to reduce the risk of strategy for effective insect pest management.

Climate change impact on insect pests in India

Insect pests cause an estimated annual loss of 13.6% globally (Benedict, 2003) and 23.3% in India (Dhaliwal *et al*., 2004). An increase of 0.4ºC average surface temperature over past century in India has led to crop insect pests losses increase from 3.0% during the pre-green revolution period to 50% during the post-green revolution period. The changes of insect pests losses has been increased up to 32%. These losses were occurred on major crops like, Rice, Wheat, Maize, Pulses, Cotton, Sugarcane, Groundnut, Other oilseeds, and Sorghum & Millets. (Dhaliwal *et al*., 2010). Losses due to insect pests are likely to increase as a result of change in crop diversity and climate change. The sugarcane woollyaphid (*Ceratovacuna lanigera*) in Karnataka and Maharashtra and the cotton mealybug (*Phenacoccus solenopsis*) in Punjab and Haryana have been affected yield losses 30% and 30-40% for sugarcane and cotton respectively. The papaya mealybug (*Paracoccus marginatus*) in Tamil Nadu, Karnataka & Maharashtra has been affected significant yield losses for papaya. The plant hoppers (*Nilaparvata lugens* & *Sogatella furcifera*) in northern India have been affected crop failure on more than 33,000 ha area for rice (Sharma, 2016). The changes in rice insect pests losses low to severe has been inference with impact of climate change on rice insect pests scenario under eastern Uttar Pradesh conditions, while increase of 0.7º C to 1º C average surface temperature and rainfall decrease to 737 mm by 2011 (Dwivedi, 2011; SAPCCUP, 2014). The climate change has affected the number of major insect pests of rice have increase from 3 to 15 (500 times) since 1965 to 2009. Meanwhile, the rice stem borers (*Scirpophaga incertulas and Chilo suppressalis*) and rice leaf folder (*Cnaphalocrocis medinalis*) have been maintaining the major insect pest status (Krishnaiah and Varma, 2009). The prediction of insect pests incidence under climate change scenarios indicated that, the *Spodoptera litura* on groundnut and *Helicoverpa armigera* on pigeonpea were expected to have two to three additional generations during distant and very distant future climate change periods due to increased temperature across majority of locations of India (Rao *et al*., 2022).

The climate change has also diverse effects on natural enemies of insect pests. The abundance of natural enemies can be altered in response to changes in insect

pests population size induced by temperature and elevated carbon dioxide concentration effects on plants. The impact of climate change factors on natural enemies is more complex and critical. The decreased grub period (23%) with increased predation capacity (19%) of *Menochilus sexmaculatus* on *Aphis craccivora* at elevated carbon dioxide concentration over ambient carbon dioxide concentration indicated that, the incidence of *Aphis craccivora* will be higher with increased predation in the future climate change scenario of India (Rao *et al*., 2022).

Climate change management for insect pests in India

The adaptation, mitigation and natural resource management are basic components of remedial measures taken to combat the adverse impact of climate change. The natural resource management is a holistic approach to minimize the adverse impact of climate change by application of sustainable approach in insect pest management. To combat the adverse impact of climate change on insect pests, its urgent need to adopt climate resilient strategies and initiatives for insect pest management in India.

Strategies for climate resilient insect pest management

The potential adaptation, mitigation and natural resource management are the prominent strategies for climate resilient insect pest management. These strategies should be mostly deal with varietal improvement, production augmentation, weather forecasting application, indigenous technical knowledge and sustainable pest management. The strategies for climate resilient agriculture are the practices conducted by farmers for their farm production for minimizing the adverse effects of changing climatic conditions. These prominent strategies in the Indian context are discussed below-

1. Varietal Improvement

The adverse impact of climate change on insect pest management could be minimize with varietal improvement. The varietal improvement helps to minimize the adverse effects of seasonality on yield potential and stress resistance of crops by increasing farm income. Varietal improvement is the development of new crop varieties with higher yield potential and multiple stress resistant by strengthening germplasm improvement programmes. The improvised germplasm with multiple biotic stress resistance like, antixenosis and antibiosis, and frostbite and tolerance will be affecting yield and varietal potential status. The crops with multiple biotic stress resistance varieties seems to be good option for reducing insect pests infestation. In the most diversified ecosystem of India, the short duration crop varieties mature before peak infestation counter yield loss due to infestation induced reduction during growing period can be brought under crop improvement and their establishment. (NAAS, 2013; NMSA, 2014; SLACC, 2019; Vanaja, 2019).

2. Production Augmentation

The adverse impact of climate change on farm production could be compensated with production augmentation. The production augmentation helps to minimize the adverse effect of climate change on production potential of crops by supplement the technology induced increasing farm production. Production augmentation is the enhancing of farm production with cost-effective higher yield potential by strengthening technology induced farming system. The production augmentation practices and its associated cultivation practice modifications will be affecting higher yield potential. Technology induced farm production with higher yield potential seems to be good option for enhancing crop production to minimising the cope of climate change. The optimizing new technologies for farm production, increasing net profit and sustainable farming will be explored to introduce in the farming systems to complement and synergize the productivity and income under changing climatic conditions. (NAAS, 2013; NMSA, 2014; SLACC, 2019; Vanaja, 2019).

3. Weather Forecasting Application

The adverse impact of climate change on farm production could be minimize with application of weather forecasting. The application of weather forecasting helps to minimize the adverse effects of seasonality and climate change on farm production potential and livelihood improvement. Application of weather forecasting is the early warning systems of weather and climate for minimizing risks of climatic vagaries. The early warning systems of weather with monitor changes in farm production seasonality will be affecting higher yield potential and livelihood status. The seasonal weather forecasts and agromet advisory services seems to be good option for minimizing the cope of climatic vagaries and change. In the rich ecosystem of India, the monitoring of changes in biotic and abiotic stresses of farm production can be brought under weather forecasting by minimising the cope of changing climatic conditions. (NAAS, 2013; NMSA, 2014; SLACC, 2019; Vanaja, 2019).

4. Indigenous Technical Knowledge

The adverse impact of climate change on farm production could be minimize with application of indigenous technical knowledge in insect pest management. The application of indigenous technical knowledge in agriculture helps to minimize the adverse effects of seasonality and climate change on farm production potential and insect pest management. Indigenous technical knowledge in agriculture is the revival of traditional agriculture knowledge of scientific rationale for sustainable agriculture production. The application of traditional agriculture knowledge of scientific rationale seems to be good option for changing climatic conditions. In the rich ecosystem of India, the traditional agriculture knowledge of scientific rationale can be brought under indigenous technical knowledge for insect pest management by minimising the cope of changing climatic conditions. (NAAS, 2013; NMSA, 2014; SLACC, 2019; Vanaja, 2019).

5. Sustainable Insect Pest Management

The adverse impact of climate change on crop production could be minimize with sustainable pest management. The sustainable pest management helps to minimize the adverse effects of seasonality on increasing crop pests incidence by increasing farm income and quality yield. Sustainable pest management is the eco-friendly pest management with higher yield potential and cost-effective crop production by minimising adverse impact on natural resources of pest management. The improved pest management practices with efficient eco-friendly approach will be affecting quality yield potential and cost-effective status of pest management. The eco-friendly pest management with approaching natural resources of pest management seems to be good option for changing climatic conditions. In the rich ecosystem of India, the integrated pest management, biointensive pest management, ecofriendly insecticide technology and ecological engineered pest management can be brought under sustainable pest management by minimising the cope of climate change on natural resources of pest management. (NAAS, 2013; NMSA, 2014; SLACC, 2019; Vanaja, 2019).

Initiatives for climate resilient agriculture

The potential efforts by government functionaries for minimizing the cope of changing climatic conditions are the prominent initiatives for climate resilient agriculture. These initiatives should be mostly deal with varietal improvement, production augmentation, weather forecasting application, indigenous technical knowledge and sustainable pest management. The National Action Plan on Climate Change (NAPCC) of India and the National Innovations in Climate Resilient Agriculture (NICRA) project of the Indian Council of Agricultural Research (ICAR) has made excellent initiatives towards rendering Indian agriculture more resilient to climate change. These prominent initiatives are discussed below-

1. National Action Plan on Climate Change (NAPCC)

The aims to enable the country to adapt the climate change and enhance the ecological sustainability, the government of India has been launched a national strategic plan as National Action Plan on Climate Change (NAPCC) in the year 2008. The National Action Plan on Climate Change is an integration of many statutory plans. It is an amalgamation of eight missions, each of which caters to the improvement of national prospects on the threats posed by climate change and the measures proposed by India to counter them. They focus on promoting understanding of climate change, adaptation, mitigation, energy efficiency and natural resource management. The National Mission for Sustainable Agriculture (NMSA) aim is to make Indian agriculture more resilient to climate change by identifying conservation agriculture, production augmentation, crop diversification, varietal improvement, soil and water management, sustainable pest management, weather forecasting application and harnessing indigenous technical knowledge in agriculture., as well as finance and insurance mechanisms. (NAPCC, 2008, NMSA, 2014; Rattani, 2018)

2. National Innovations in Climate Resilient Agriculture (NICRA)

The aims to enhance resilience of Indian agriculture to climate change and their variability, the Indian Council of Agricultural Research (ICAR), New Delhi has been launched a national strategic research and technology demonstration network project as National Innovations in Climate Resilient Agriculture (NICRA) in the year 2011. It was formerly known as National Initiative on Climate Resilient Agriculture (NICRA). The National Innovations in Climate Resilient Agriculture is a flagship program of the Indian Council of Agricultural Research to undertake systematic long-term research on the impacts and adaptation of Indian agriculture and frontline demonstration of best practices to minimize the cope of climate change. This has been carried out in 151 vulnerable districts of the country. The National Innovations on Climate Resilient Agriculture is an integration of many village level intervention strategies. It is an amalgamation of ten intervention strategies, each of which caters to the improvement of national prospects on location specific interventions in vulnerable districts of India to enable farmers cope with current climatic variability. ten intervention strategies. (CRIDA, 2016; Prabhakar, 2019; Vanaja, 2019)

CONCLUSION

The importance of climate and weather events to the distribution of insects and their population dynamics has long been recognized. Insects are poikilothermic in nature and are directly under the control of temperature for their growth. Several insect pests, that were important in the past or the minor pests are likely to become more devastating with global warming and climate change. The adaptation, mitigation and natural resource management are basic components of remedial measures taken to combat the adverse impact of climate change. To combat the adverse impact of climate change on agriculture, its urgent need to adopt climate resilient strategies and initiatives for agriculture in India. The strategies and initiatives should be mostly deal with sustainable pest management, production augmentation, varietal improvement, weather forecasting application and harnessing indigenous technical knowledge. The National Action Plan on Climate Change (NAPCC), National Mission for Sustainable Agriculture (NMSA) and National Innovations in Climate Resilient Agriculture (NICRA) are major initiatives for climate resilient insect pest management in India.

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Research Article

Under Long -Term Field Experiment The Effects of Organic and Inorganic Fertilizers Application on Maize Growth and Soil Organic Carbon Sequestration

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ABSTRACT
A long-term field experiment was established in 1996 at Çukurova University Research and Application Farm, Adana, Turkey. The design of experiment was The Randomized Complete Block Design (RCBD) with 5 different fertilizer treatments: control (no fertilizer), Mineral fertilizer (NPK), Animal manure (25-ton ha^{-1}), Compost (25-ton ha^{-1}) and Compost + Mycorrhiza (10-ton ha^{-1}). Maize seeds were sown and harvested in 2022. At harvest, soil samples (at 0-15 and 15-30 cm depths) and plant samples were taken from each plot. Soil and plant total carbon and N concentrations were determined by a CN elemental analyzer. The soil organic carbon (OC) was estimated as the difference between total and inorganic C. Results show that carbon concentration in the grain, shoot, and root samples of maize plants were higher in fertilized plots than in control treatments. Compost and animal manure treated soil had higher OC concentrations at both sampling depths. The highest values of soil OC at 0-15 cm depth were obtained in animal manure applied plots.Generally, organic fertilizer application increased soil OC % concentrations and contributed to the soil carbon budget. The PCA analysis also revealed that a majority of the plant and soil parameters clustered more closely with organic fertilizers compared to the control and mineral counterparts.
Keywords: Maize, Soil Organic carbon, Organic and Mineral fertilizer, Carbon Sequestration, Long-term field experiment

INTRODUCTION
Since the Industrial Revolution, more agricultural products have been used in order to meet the nutritional and energy needs arising due to rapid population growth. Furthermore, the soils have been more intensively used and remain under the pressure of chemical fertilizers in order to increase agricultural production. Intensive agricultural practices and uncontrolled application of fertilizers negatively affected soil microbial activity and soil productivity (Aksahin et al., 2021). Intensive exploitation of agricultural lands not only has a negative effect on sustainability but also reduces the amount of organic matter in the soil, thus increases the emission of carbon dioxide (CO_2) and other greenhouse gases (GHGs) to the atmosphere. The atmospheric concentration of CO_2 gas was 280 ppm before the industrial revolution (Ortas et al., 2017), and it has reached 420 ppm in 2022 (SOEST, 2022).
The increase in GHGs concentration in the atmosphere give rise to numerous adverse conditions on our planet. Global warming and climate changes are at the forefront of these negative situations. These changes bring many disasters and affect agriculture, which directly affects human life and constitutes the main source of nutrition. It is vital that agricultural systems are manageable in order to reduce CO_2 emissions, which are shown as the main cause of global warming (Ortas, 2022). It is necessary to develop and implement a number of agricultural methods in order to reduce the emission of greenhouse gases and to bind CO_2 into the soil. The application of organic fertilizers, such as compost and manure, to the soil is a significant process that has been practiced for many years. The well-known organic fertilizers such as animal manure, compost and mycorrhizal fungi, make substantial contributions to the incorporation of organic materials into the soil. Consequently, they have a positive impact on soil carbon sequestration and the enhancement of soil fertility (Aksahin et al., 2021).
In light of the above information, the objective of this study is to investigate the potential effects of applying organic fertilizers (including mycorrhizal inoculation) and inorganic fertilizers to the soil. Specifically, we aim to determine whether such applications can increase the overall carbon content and organic carbon content of the soil. Additionally, we seek to evaluate whether these applications will have a long-term impact on the soil carbon budget. The hypothesis tested is that organic fertilizer sources applied to the soil under field conditions will increase the total carbon and organic carbon of the soil.

MATERIALS AND METHODS

The trial was established in Adana, (in the eastern part of the Mediterranean region of Turkey) at Çukurova University Research Farm, on the Menzilat soil series (Typical Xerofluvents) in 1996 and continues to function today. The image of the trial area is given in Figure 1, and the soil properties are given in Table 1. The trial consists of 5 applications, and the applications applied in the trial are listed as follows. (i) control; (ii) conventional N-P-K fertilizers (160 kg N ha^{-1} as K_2SO_4, 83 kg K ha^{-1} and 26 kg P ha^{-1} as $(NH_4)_2SO_4$, as 3Ca $(H_2PO_4)_2H_2O$); (iii) compost at 25 Mg ha^{-1}; (iv) animal manure at 25 Mg ha^{-1}; and (v) mycorrhiza inoculated compost at 10 Mg ha^{-1}. Before each trial, organic fertilizers (animal manure, compost and mycorrhizae) were thrown onto the soil surface just before planting and were layered with a disc harrow to a depth of 15 cm. Soil samples were taken from 2 different depths (0-15 cm and 15-30 cm) for each parcel in 2022. Grain, shoot and root samples were taken on the same date. Soil samples taken were dried at room temperature, ground and passed through a 2 mm sieve for soil analysis. In addition, the soil was ground again and passed through a 0.25 mm sieve to determine the total C and N concentrations. C and N analyzes of soil and plant samples were performed by the dry burning method at 900°C using a CN elemental analyzer (Fisher-2000).

Table 1. Characteristics of Menzilat Soil in 1996 (Ortas and Lal, 2014).

Parameters	Unit	0-15cm Depth		15-30 cm Depth	
Clay		318.8	±30.6	333.4	±21.8
Silt		360.9	±87	379.5	±13.4
Sand		320.3	±23.0	287.2	±16.4
Organic C Soil		0.96	±0.08	0.78	±0.08
İnorganic Carbon	g kg^{-1} soil	3.77	±0.35	3.97	±0.42
Total N		0.08	±0.01	0.07	±0.01
CEC	Cmol^{+} kg^{-1}	20.50	±2.00	17.90	±1.64
pH	H_2O	7.58	±0.66	7.60	±0.71
Salt	%	0.05	±0.00	0.04	±0.00
P		22.60	±2.16	20.20	±2.00
Fe		5.43	±0.82	5.66	±0.58
Mn	mg kg^{-1}	5.74	±0.32	5.31	±0.59
Zn		0.52	±0.05	0.23	±0.02
Cu		1.86	±0.19	1.56	±0.16
AMF spores	10 g^{-1} soil	64.00	±11.70	44.00	±2.62

Mean of three replicates ±SD.

Using a calcimeter (of the Schibler type), the total $CaCO_3$ concentration was measured in order to ascertain the amount of inorganic C. SOC concentration was calculated by deducting inorganic C from the total amount of C in the soil (Ortas et al., 2013; Ortas and Bykova, 2020). The obtained data were analyzed by using Tukey in the Anova statistical model with the JMP16 statistical software to evaluate the effects of different treatments on soil properties. In addition, principal component analyze (PCA) were performed with the help of XLSTAT-14 Statistical Software, and correlation analysis with the Origin Pro package program.

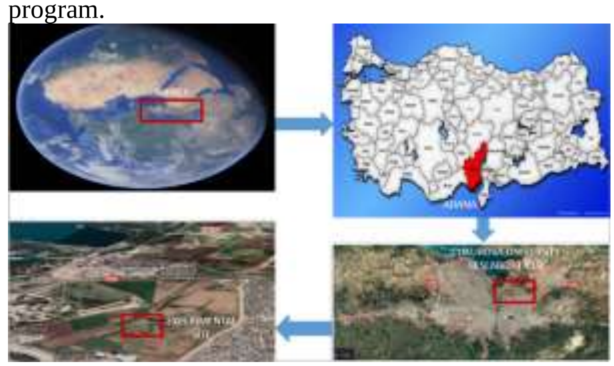

Figure 1. A View of the Trial Area (Aksahin et al., 2021)

RESULTS AND DISCUSSION

Total Soil Organic carbon, Nitrogen and Phosphorus

In the field experiment where different organic and inorganic applications were applied for a long time, the total organic carbon and total nitrogen content of the soil are given in Figure 2. The plots in which different long-term organic treatments were applied gave higher results than the control application. When the results obtained were examined, it was seen that the highest results were obtained in the plots where organic fertilizers were applied at both depths. According to the results obtained, there were differences between the fertilizers, but these differences were not statistically significant.

When the total organic carbon data were examined, the highest value (53.92 Mg ha^{-1}) was obtained in the plot where animal manure was applied at 0-15 cm soil depth, while the lowest value (31.67 Mg ha^{-1}) was obtained in the control. At the 15-30 (R 15-30) cm depth of the soil, the highest total organic carbon value (57.23 Mg ha^{-1}) was obtained in the plot where mineral fertilizer was applied, while the lowest value (16.86 Mg ha^{-1}) was obtained in the control application (Figure 2).

When we increase the amount of carbon stored in the soil, especially organic carbon, we both reduce the greenhouse gas effect and increase the microbial activity living in the soil. Increasing microbial activity is very important for plant and soil health. Increasing the amount of organic carbon in the soil has a positive effect on plant growth, and as a result, it is extremely important to reduce the atmospheric CO_2 concentration (Aksahin et al., 2021). Long-term application of organic fertilizers to the soil instead of mineral fertilization can increase the microbial activity of the soils and will also add organic carbon to the soils. Adding organic matter to the soil significantly affects soil carbon dynamics such as soil carbon pool (Ortas et al., 2013). Batjes (1996) noted that predicted global warming could have significant effects on the size of the soil organic carbon pool and directly affect the atmospheric greenhouse gas concentration. Previous studies on the subject support our findings. For instance, compost, animal manure, and compost+mycorrhiza applications applied to the soil was

reported to increase the SOC and N % compared to the control (Ortas et al., 2013).

When the total nitrogen data were examined, the lowest value in R-0-15 was obtained in the control (2.83 Mg ha^{-1}) application, while the highest value (4.57 Mg ha^{-1}) was obtained in the plot where animal manure was applied. Looking at the nitrogen data at a depth of 15-30 cm, the lowest value (3.10 Mg ha^{-1}) was obtained in the control, while the highest value (3.76 Mg ha^{-1}) was obtained in the application of mineral fertilizer (Figure 2).

Studies on the subject have reported that soil organic carbon and nitrogen are related to organic fertilizers applied to the soil. Organic fertilizer application to the soil increases the organic carbon and total nitrogen content of the soil (Bokhtiar and Sakurai, 2005). Malhi et al. (2006) reported that the amount of TN and TOC was lower in areas where stubble (organic mulch) was not applied than in areas where stubble was applied.

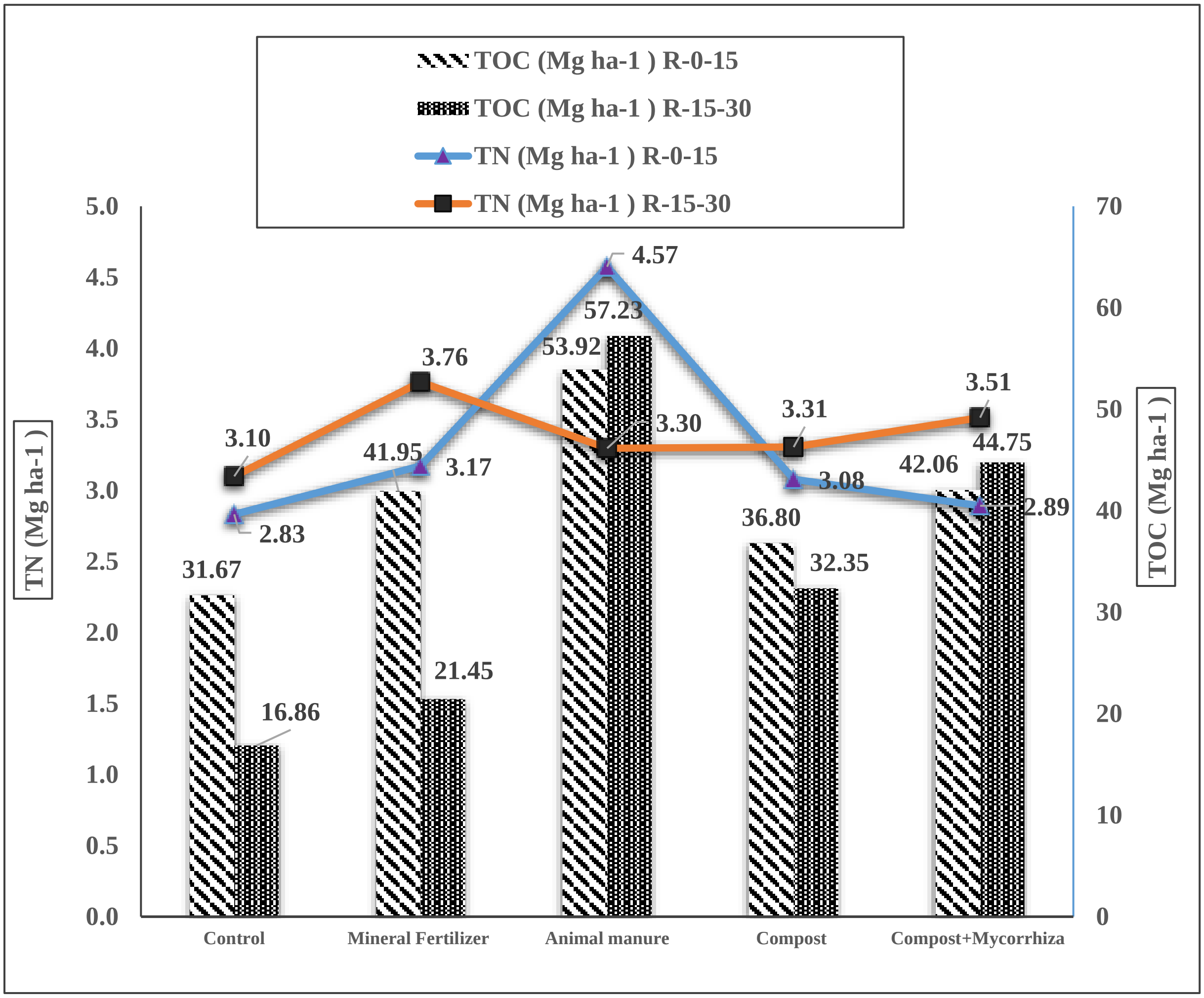

Figure 2. Soil Total Organic Carbon (TOC) and Soil Total Nitrogen.

In the study examining the effect of organic and inorganic fertilizers applied to the soil for a long time, the changes in the available phosphorus (P_2O_5) of the soil were revealed and given in Figure 3. According to the results, animal manure at both depths had the highest values, while the control had the lowest values. While the values obtained in animal manure were given for 0-15 cm depth and 15-30 cm depth (171.91 P_20_5 kg ha^{-1} and 171.40 P_20_5 kg ha^{-1}), respectively. The lowest values were obtained for both depths in the control application, with 40.32 kg ha^{-1} of P_20_5 for the 0-15 cm depth and 83.94 kg ha^{-1} of P_20_5 for the 15-30 cm depth (Figure 3).

Erdal and Aydemir (2003) reported that rose pulp applied at increasing doses resulted in significant increases in the P content of the soil. Lee et al. (2004), NPK + applied to paddy soils for 31 years, investigated the changes that compost (straw origin) brought about in the phosphorus fractions of the soil, It was determined that the continuously applied fertilizer increased the total and inorganic phosphorus content in the plow layer of the soil, while the amount of mineral P did not change when only inorganic fertilizer was applied (NPK). The researchers concluded that the time dependent increase in total P, inorganic P, and extractable phosphorus was closely related to the availability of phosphorus accumulated in the soil.

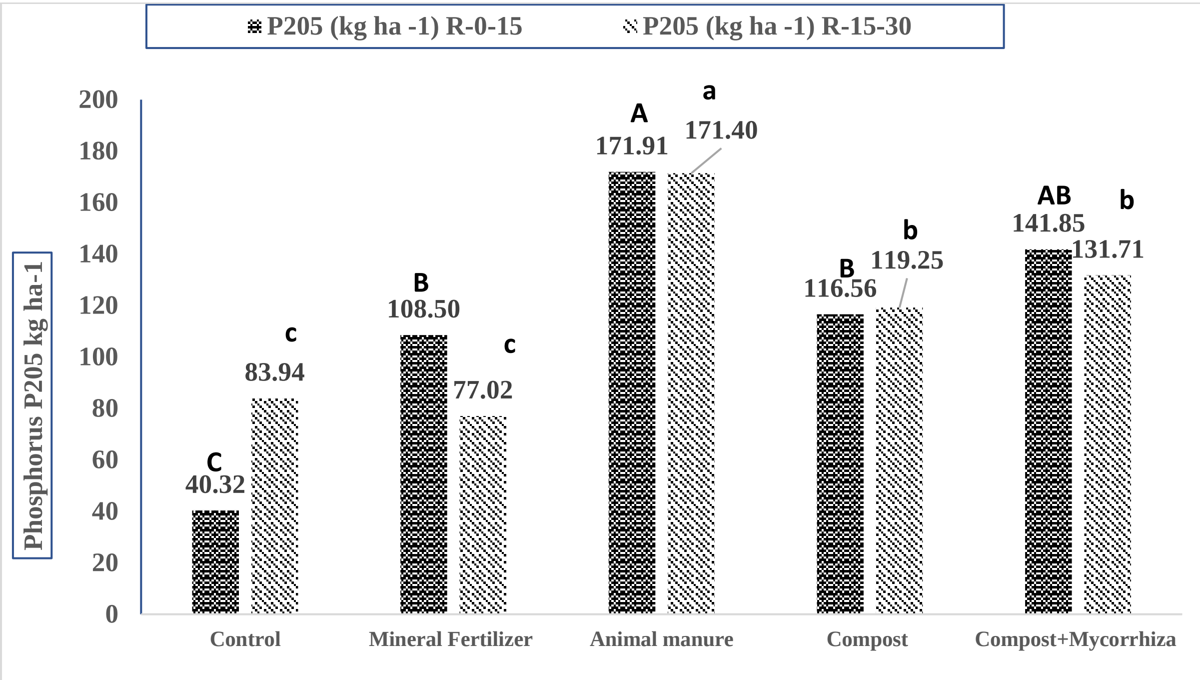

Figure 3. Available (can be taken) P_2O_5 Values in Kilograms Per Hectare at Different Depths.

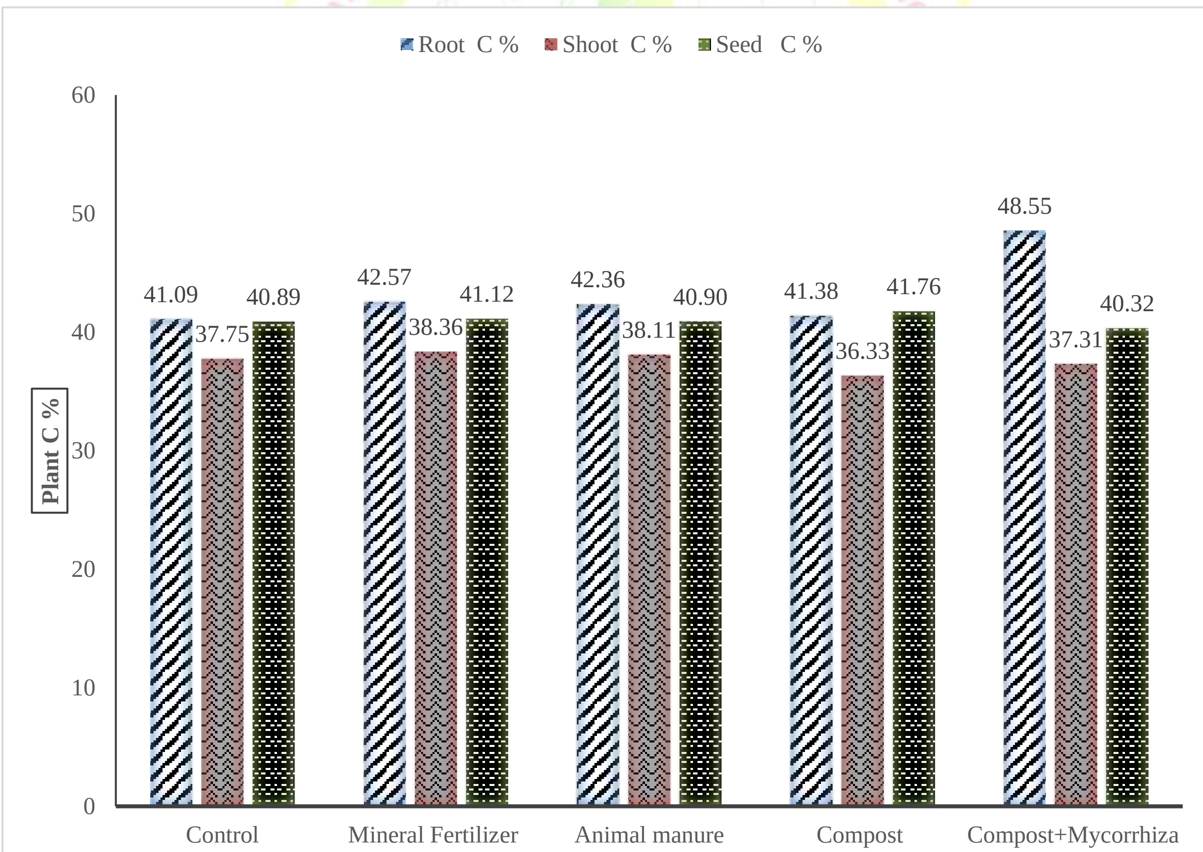

Figure 4. Carbon Percentages in Different Parts of The Plant Under Different Treatments.

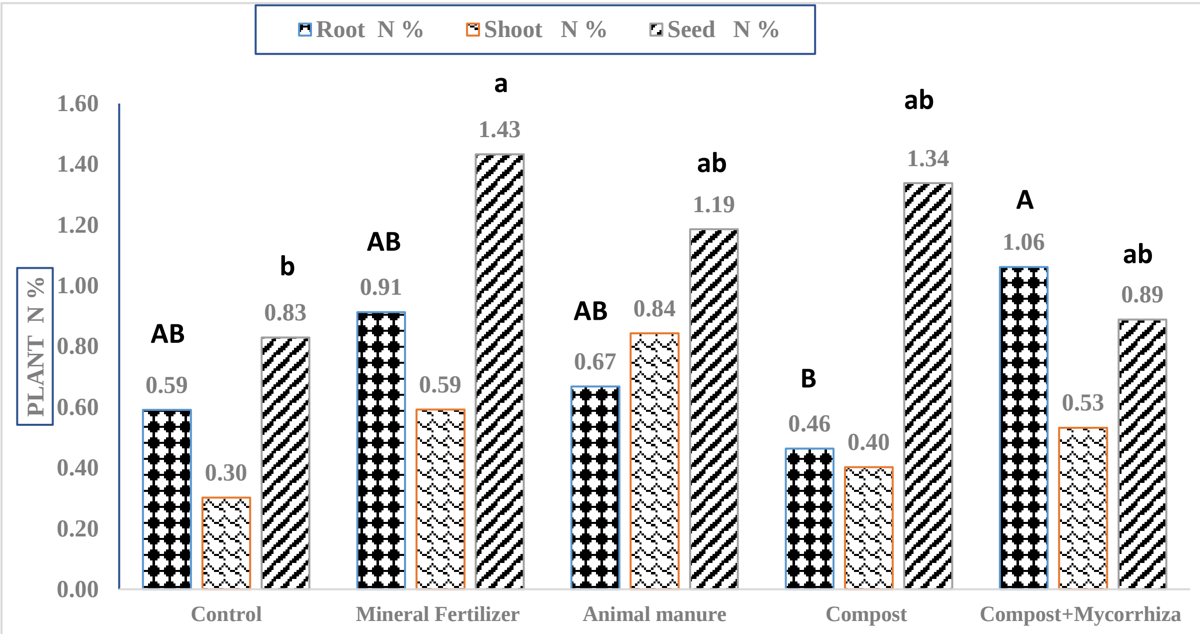

Figure 5. Nitrogen Percentages in Different Parts of The Plant Under Different Treatments.

The Carbon and Nitrogen Percentages of the Plant

Figure 4 shows the percentage carbon contents of the plant sections (root, root, and grain) of the maize plant grown in the field experiment with various fertilizers. The parameters that were acquired after applying various organic and inorganic applications for a long time showed differences between the treatments, although these changes were not statistically significant.

When the collected data are evaluated, it becomes clear that the pots with organic fertilizer applied had the greatest values in comparison to the control. Compost plus mycorrhiza produced the highest root carbon percentage (48.55%), inorganic fertilizer produced the highest shoot carbon percentage (38.36%), and compost produced the highest seed carbon percentage (41.76%). The nitrogen percentage values of the maize plants were different in between organic and inorganic fertilizers applications (Figure 5). The differences between the nitrogen percentages in the root and the grain were found to be statistically significant, while the difference in the shoot nitrogen percentage data was not. The highest root, shoot and seed N % values were obtained in compost+mycorrhiza (1.06 %), animal manure (0.84 %) and inorganic fertilizer (1.43%) applications, respectively. The lowest root, shoot and seed N % concentrations were obtained in compost (0.46 %), control (0.30 %) and control (0.83 %) respectively (Figure 5.)

When the % C and % N concentration of the plant (seed, shoot and root) were examined, it was seen that in the all treatments, especially organic fertilizer applied samples have higher concentrations than the control. Özkan et al. (2013) reported that different organic and inorganic fertilizers, applied in greenhouse pepper cultivation, increased N % compared to control. It was also reported by (Chirinda et al., 2012) that the root C was higher in spring barley and wheat than in organic fertilizer-based inorganic systems. Also preciously (Aksahin et al., 2021) in the same field experiment conditions, animal manure, compost and com+myorriza treated plants C and N concentrations were higher than in control application. The information obtained and the literature support each other.

P, K and Zn Concentrations in Different Parts of The Plant Tissue

The zinc concentration values of the maize plant are given in Figure 6. The highest seed zinc concentration was obtained in the compost application as 22.80 mg Zn kg^{-1}, while the lowest zinc concentration was obtained as 11.96 mg kg^{-1} in the control application. Considering the root zinc concentrations, the highest zinc concentration was obtained in animal manure application as 24.25 mg kg^{-1} , while the lowest zinc concentration was obtained in mineral fertilizer application as 10.20 mg kg^{-1} . When we look at the shoot concentrations of the maize plant, the highest concentration was 61.10 mg kg^{-1} in the control application, but the lowest zinc concentration was 35.77 ppm in the inorganic fertilizer application (Figure 6).

Potassium (K) concentrations of the maize plant is given in Figure 7. The highest seed K concentration was 0.39% found in compost + mycorrhiza application, while the lowest K concentration (0.32%) was in mineral fertilizer application. The highest K concentration in the root was obtained as 1.39 % in compost application, while the lowest K concentration was obtained in the control application as 0.25 %. The highest maize shoot K concentration was measured in the control application, as 0.98%, the lowest K was 0.76% in the compost + mycorrhiza application (Figure 7).

Phosphorus (P) concentrations of the maize plant are given in Figure 8. When the phosphorus concentrations of maize plants were examined, the highest seed P concentrations were obtained as 0.25 % in animal manure, compost and compost+mycorrhiza applications, while the lowest seed phosphorus concentrations were obtained as 0.22 % in inorganic fertilizer and control applications. The highest shoot P concentration was mesured in animal manure treated plots at 0.29%, and the lowest shoot P concentrations were found in inorganic fertilizer at 0.12%. When we look at the root P concentration, the highest concentration was obtained in the compost application as 0.26 %, but the lowest root phosphorus concentration was obtained as 0.08 % in the inorganic application (Figure 8).

In previous studies about the effect of different organic and inorganic fertilizers on the nutrient content of the plants, it has been seen that the effect of organic fertilizers on plant nutrient intake and content is generally positive. Kan (2011) compared organic and inorganic fertilizers, and in his study, the highest P content (15.059%) and the highest zinc content (0.108 ppm) were obtained from a 20 t ha^{-1} organic fertilizer application. Zafer et al. (2019) reported that the highest values in terms of K content were obtained in chicken manure compared to control and chemical fertilizers in their study to determine the effects of solid vermicompost and chicken manures on yield, some quality characteristics, and the plant nutrient content of lettuce. Kocabaş et al. (2007) reported in their study with various organic fertilizers that the highest P content in Sage (*Salvia officinalis*) was observed with the application of sheep manure + cattle manure. They also found that the highest K values were associated with chicken manure applications, while the highest Zn value was observed in the control application. (Aksahin and Gülser, 2019), conducted a study by using organic wastes, in where they found a statistically significant increases in the P concentration of plants with higher doses of tea waste application. They also found an increase in K content with tea waste applications. These findings are consistent with the present research results.

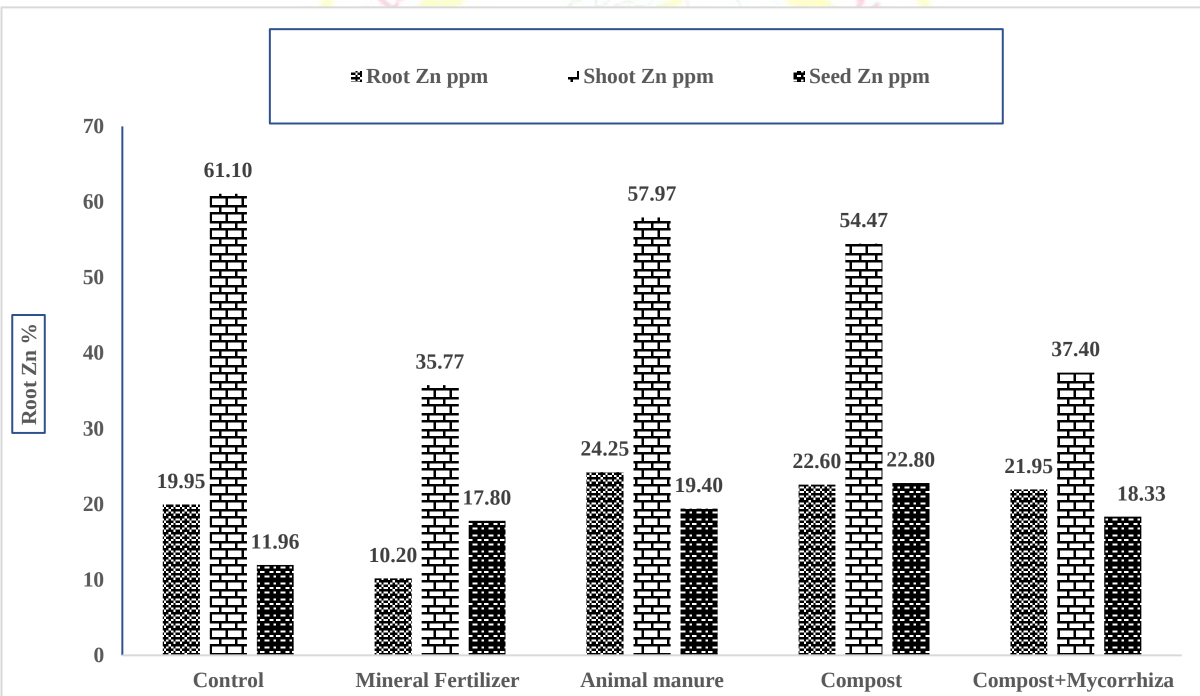

Figure 6. Zinc concentration in different parts of the plant.

Correlation and Principal Component Analysis (PCA)

The correlation of the parameters obtained as a result of the application of different organic and inorganic fertilizers is given in Figure 9. When the data obtained are examined, it is seen that there is a positive correlation between the total organic carbon content of the soil and the nitrogen uptake of the plant and the total N and P of the soil, and this correlation is statistically significant. Addationaly, it is observed that there is a positive correlation between the total nitrogen content of the soil and the nitrogen uptake of the plant, and this correlation is statistically significant. However, it is also seen that there is a negative correlation between the total nitrogen content of the soil at a depth of 15-30 cm and the zinc uptake of the plant (Figure 9).

Principal component analysis (PCA) analysis technique was applied in order to determine the relationships between applications and parameters in the data obtained as a result of the application of different organic and inorganic fertilizers. Result of PCA analysis are given in Figure 10. When the results of different organic fertilizer applications are examined, it is seen that there is a 38.77 percent change in the F1 value in the x-axis and a 26.74

percent change in the F2 value in the y-axis. Since the obtained F1+F2 value is over 60% (65.51%), it is seen that the data in the PCA analysis are well-explained. It is seen that Eingenvalue values are above 1 for all F values. There is a positive correlation between the application of organic fertilizers and the measured parameters, as can be seen by the fact that the majority of the parameters obtained as a result of the application of organic and inorganic materials cluster in the areas where they are present. It is seen that control and inorganic fertilizers are not much effective on the parameters obtained compared to organic fertilizers aplications. Also it has been observed that plant-related parameters are mainly clustered in the area where compost is manly applied. Aksahin et al. (2021) reported that the plant parameters clustered in the area where the compost was located in the data obtained in their study. Applications of compost plus mycorrhiza and animal manure were found to have greater effects on the soil's overall carbon, nitrogen, and phosphorus contents. When organic fertilizers were supplied, all parameters—aside from root nitrogen, shoot carbon, and nitrogen % at 15–30 cm depth—clustered in the favorable region. As a result, it can be shown that the treatments of animal manure, compost, and compost plus mycorrhiza had a favorable impact on the parameters measured (Figure 10).

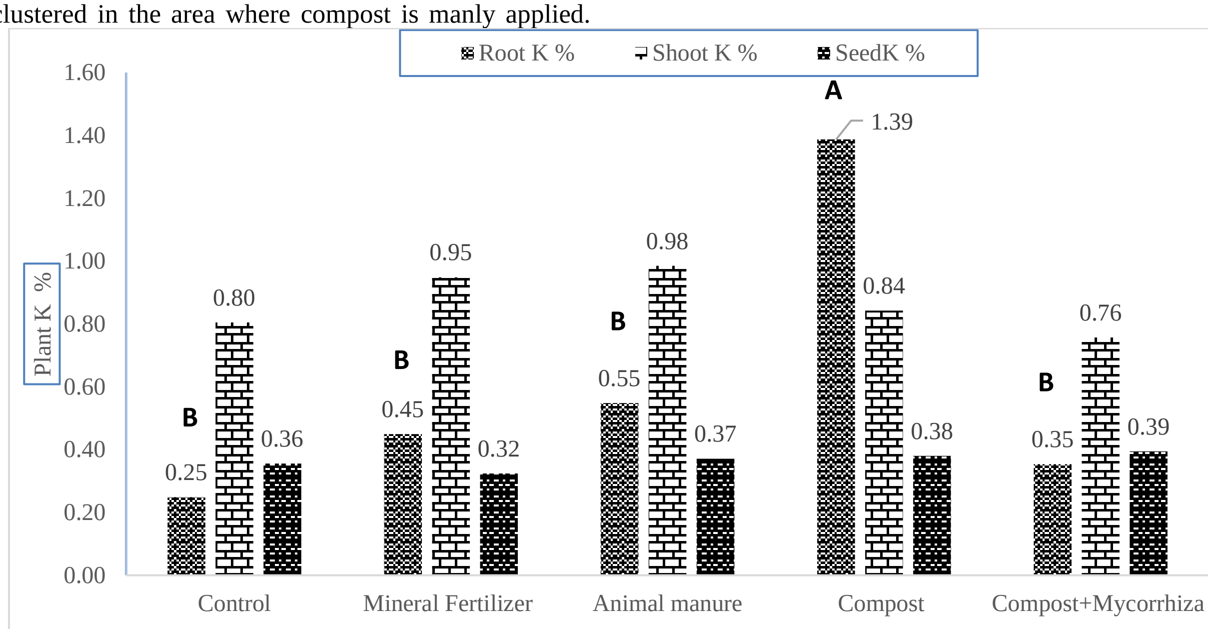

Figure 7. Potassium percentages in different parts of the plant.

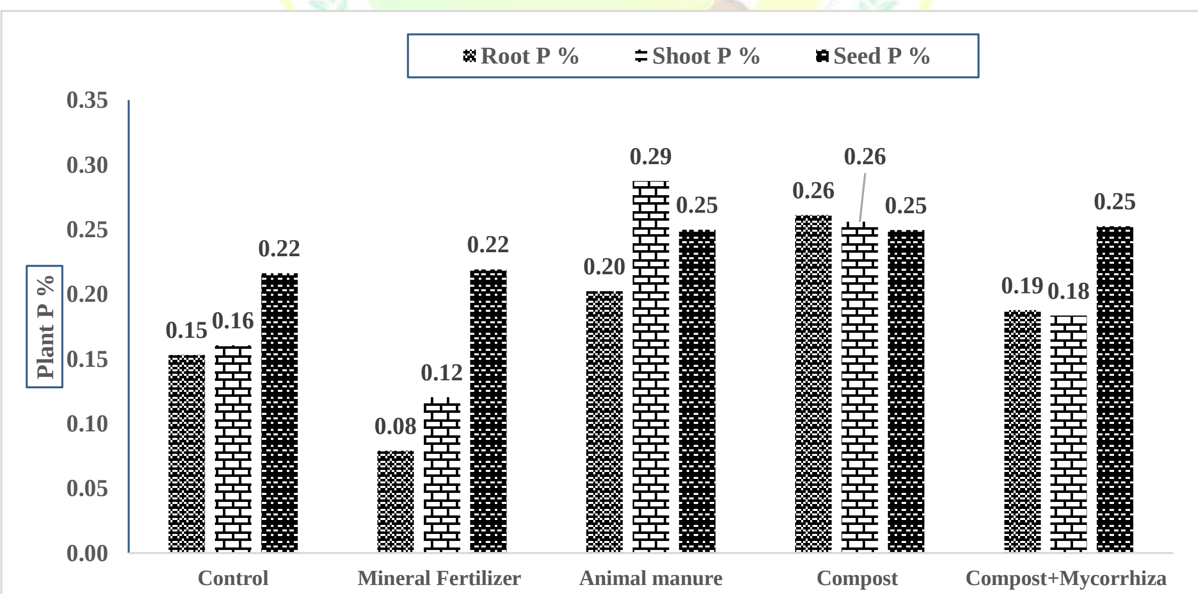

Figure 8. Phosphorus percentages in different parts of the plant.

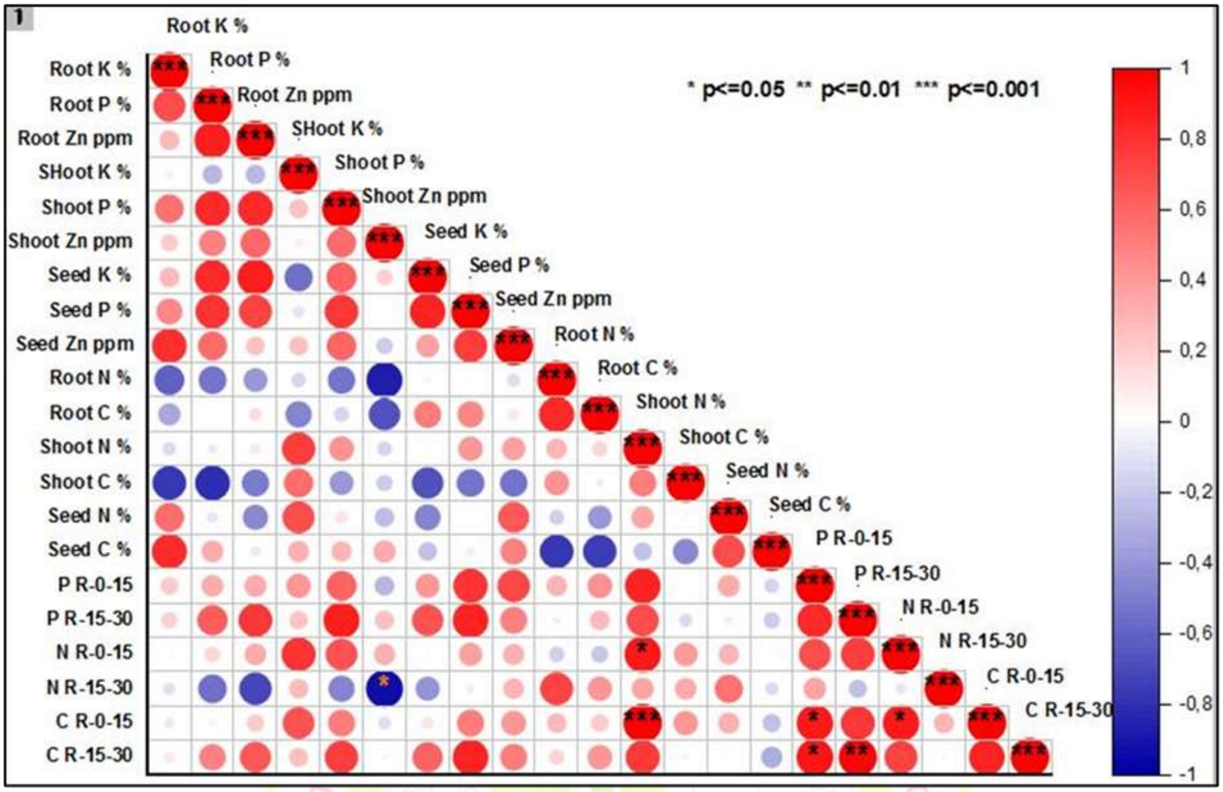

Figure 9. Correlation of Soil and Plant Parameters obtained by the application of different Organic and Inorganic applications. *R 0-15 (Represents the region 0-15 cm depth) R 15-30 (Represents the region 15-30 cm deep).*

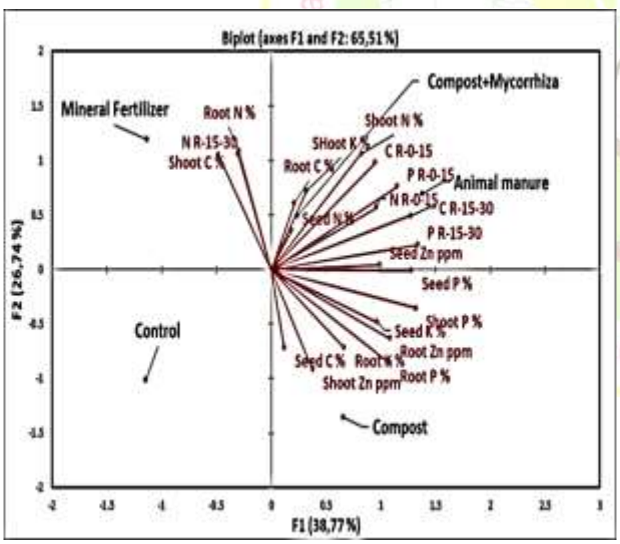

Figure 10. Principle component analysis (PCA) of soil and plant parameters obtained by the application of different Organic and Inorganic applications. *R 0-15 (Represents the region 0-15 cm depth) R 15-30 (Represents the region 15-30 cm deep).*

CONCLUSION

The obtained results in the study, in which different organic and inorganic fertilizer applications were applied, are given in the form of substances. The highest soil total organic carbon, total nitrogen and P_2O_5 concentration were obtained in animal manure applied plots. The highest plant (root, shoot and seed) carbon and nitrogen concentrations were generally obtained in organic fertilizers treated plots. The highest values of phosphorus and potassium concentrations in all parts of the plant were obtained in the plots where organic fertilizers were applied. The highest root and seed Zn concentrations were obtained in animal manure and compost, while the highest root zinc concentration was obtained in the control treated plots. The PCA analysis results shown that almost all the parameters obtained were clustered in the plots where organic fertilizers were applied.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

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Effects of Inorganic and Organic Fertilizers on the Growth of Chickpea Plant and Soil Organic Carbon and Nitrogen Contents

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ABSTRACT
Rapid economic and population growth has led to rising atmospheric greenhouse gas emissions, necessitating adequate soil and crop management for enhanced CO_2 absorption. Plant and soil microorganisms have various effects on atmospheric CO_2 capturing. Chickpea (*Cicer arietinum* L.), a leguminous plant, establishes a symbiotic association with rhizobium bacteria and mycorrhizal fungi, enabling it to fix atmospheric nitrogen (N_2) and sequester more CO_2 into the biomass and then to the soil. However, the application type of fertilizers influences this plant's growth and soil's capacity to retain carbon (C). In this background, the current research aimed to explore the impact of various organic and inorganic fertilization methods on the growth and nutrient content of chickpea plants and nitrogen content and soil organic carbon. A long-term field trial was started in 1996 at Çukurova University Research Center, with the five treatments such as Control (without fertilizer), Animal manure (25 t ha^{-1}), Mineral fertilizer (NPK), Compost (25 t ha^{-1}), and Mycorrhiza + Compost (10 t ha^{-1}). Chickpeas were planted and harvested in 2020. During harvesting, plant samples at 1 m^2 area, and soil samples at 0 to 15 cm and 15 to 30 cm depths were taken. The shoot, root and pod fresh biomass and tissue C, P, K, N, and Zn concentrations were determined. Similarly, the soil P, organic C and total N concentrations were determined. The results of the study indicate that mineral fertilizer resulted in a notable enhancement in the shoot, root and seed biomass of chickpea plants. Furthermore, mineral fertilizer resulted in a higher concentration of carbon in the roots, while the treatments involving animal manure, compost +AMF, and compost showed higher concentrations of K in both shoots and seeds. Seed P concentration was higher when animal manure was applied and exhibited similarity to the compost treatment. In terms of soil properties, the application of animal manure led to increased levels of soil organic carbon and P. Moreover, the compost treatment showed an increase in organic carbon in deeper soil depth. At 15-30 cm soil depth, both animal manure and compost treatments contributed to improved levels of total nitrogen. The good effects of organic fertilizers on soil fertility and nutrient levels in sustainable farming practices are highlighted by these findings. When compared to mineral fertilizer, animal dung specifically showed considerable improvements in soil organic carbon, nitrogen, and phosphorus.
Keywords: Chickpea, long-term field trial, soil organic carbon, organic fertilizer, and mycorrhizae

INTRODUCTION

In semi-arid climatic regions, such as the Mediterranean part of Turkey, soil degradation issues have resulted in low levels of soil organic carbon (SOC). These regions are characterized by specific challenges, including high temperatures, elevated levels of calcium carbonate ($CaCO_3$) and clay, and intensive tillage practices. Consequently, the decline in SOC has had a detrimental impact on agricultural production. Other contributing factors to the reduction in SOC levels include the burning of crop residues (Ortas, 2029) and accelerated erosion. It is crucial to highlight that effective soil and crop management practices have a substantial influence on various soil properties, including the SOC pool. Specifically, the use of inorganic and organic fertilizers may have a considerable impact on SOC levels. Implementing appropriate soil and crop management strategies, along with judicious utilization of fertilizers, becomes crucial in replenishing and improving the SOC pool in semi-arid regions (Ortas and Lal, 2014).

The application of organic fertilizers is a highly effective strategy for augmenting SOC levels and enhancing crop micronutrient content, surpassing the benefits of using mineral fertilizers alone (Lal, 2009). Increasing the use of organic amendments is regarded as a soil carbon-saving practice, as it helps preserve and build up soil carbon stocks. The addition of favorable impact on soil quality by improving the availability of nutrients, enhancing soil structure, and encouraging a greater

abundance and diversity of soil organisms (Ortas, Akpinar and Lal, 2013; Willekens, Vandecasteele and De Neve, 2014). Furthermore, integrating organic amendments serves a crucial function in augmenting the stability of SOM, thereby ensuring its long-term presence and the associated benefits in the soil. Efficiently sequestering SOC is of utmost importance in mitigating greenhouse gas emissions and reducing the carbon footprint associated with agricultural practices (Jarecki and Lal, 2003).

Crop species have a significant impact on improving soil properties by engaging in rhizospheric processes (Ortas and Lal, 2014). These processes involve the interactions between plant roots and the adjacent soil, leading to physical, chemical, and biological enhancements. Legume crops serve a dual purpose in agricultural practices, playing a vital role in human nutrition as well as in enhancing soil fertility/quality through biological N fixation. Amongst the legumes, the chickpea (*Cicer arietinum L.*), is a globally cultivated grain legume crop of significant importance. It holds a prominent position as the third most crucial food legume worldwide. Renowned for its high nutritional value, chickpea serves as a highly nutritious pulse. With a remarkable protein content of 25%, it surpasses all other pulses in this aspect. Additionally, it contains 60% carbohydrates, making it an ideal addition to enhance the nutritional composition of one's diet (Kumar, Berggren and Mårtensson, 2001). Consequently, there exists an opportunity to enhance pulse productivity by improving soil fertility and productivity through various means. This includes increasing SOC, improving the capacity of soil to store moisture, and implementing incorporated practices for nutrient and pest management. By optimizing the nutrient requirements of crops at different stages, the productivity of pulses can be significantly improved within organic production systems. In such systems, the management of organic matter plays a vital role in improving soil fertility and overall productivity (Naik, Patel and Patel, 2014). Many leguminous plants establish tripartite symbiotic relationships involving both arbuscular mycorrhizal fungi (AMF) and rhizobia. The partnership with rhizobia primarily facilitates the conversion of nitrogen in the atmosphere into a usable form, whereas the collaboration with AMF influences the plant's capacity to absorb phosphorus (Champawat, 1990; Lodwig et al., 2003) and micronutrients (Ortaş, 2008). Fertilization also has an impact on the effectiveness of this association, soil C sequestration, and crop productivity.

Despite the extensive use of organic and inorganic fertilizers, limited research has focused on evaluating their long-term effects on SOC levels and crop production. Therefore, the current study aims to close this research gap and provide useful information by conducting a comprehensive evaluation of the long-term impacts of fertilization on plant production and soil quality. The aim of this study is to find out the effect of prolonged (26-years) application of different organic and inorganic fertilizers on SOC and N levels as well as on the growth, and mineral nutrition of chickpea plants. Through this research, we intend to identify the most effective fertilization strategies that promote soil carbon storage, maximize crop productivity, and support long-term sustainability in agricultural systems.

MATERIALS AND METHODS

Site Descriptions and Experimental Setups

A long-term field study was initially established in 1996 within the Menzilat soil series (Typic Xerofluvents), and the soil properties are provided in Table 1. The study site is situated at the Research Farm of Cukurova University (37°-00'54.31''N longitude and 35°-21'21.56''E latitude and 34 m above mean sea level) in Adana-Turkey, which is located in the eastern part of the Mediterranean region. Since 1996, five treatments such as: (i) a control group (no fertilization), (ii) conventional mineral fertilizer (N-P-K ,consisting of 160 kg N ha^{-1}, 83 kg K ha^{-1}, and 26 kg P ha^{-1}, (iii) compost application at a dose of 25 t ha^{-1}, (iv) animal manure application at 25 t ha^{-1} rate, and (v) mycorrhiza inoculation combined with 10 t ha^{-1} of compost addition, have been applied. The study had a completely randomized block design with three replicates. Prior to compost application, the mycorrhizal inoculum cocktail was carefully blended with the compost material. After each harvest, all plots underwent moldboard plowing to a depth of 20 cm. For each cropping season, the organic fertilizers were evenly applied across the soil surface, considering the soil moisture levels immediately prior to sowing. Subsequently, they were incorporated into the uppermost part of the soil, approximately 10-15 cm deep, using a disc harrow. The control and fertilizer-amended plots followed similar tillage practices throughout the experiment.

Table 1. The soil characteristics of Menzilat soil in 1996 were documented by (Ortas and Lal, 2014).

Parameters	Unit	0-15cm Depth		15-30cm Depth	
Clay		318.8	±30.6	333.4	±21.8
Sılt		360.9	±87	379.5	±13.4
Sand		320.3	±23.0	287.2	±16.4
Organic C Soil		0.96	±0.08	0.78	±0.08
İnorganic Carbon	g kg^{-1} soil	3.77	±0.35	3.97	±0.42
Total N		0.08	±0.01	0.07	±0.01
CEC	$Cmol^{+}$ kg^{-1}	20.50	±2.00	17.90	±1.64
pH	H_2O	7.58	±0.66	7.60	±0.71
Salt	%	0.05	±0.00	0.04	±0.00
P		22.60	±2.16	20.20	±2.00
Fe		5.43	±0.82	5.66	±0.58
Mn	mg kg^{-1}	5.74	±0.32	5.31	±0.59
Zn		0.52	±0.05	0.23	±0.02
Cu		1.86	±0.19	1.56	±0.16
AMF spore counts	10 g^{-1} soil	64.00	±11.70	44.00	±2.62

Mean of three replicates ±SD.

Soil and Plant Sampling, Preparation, and Analyses

Soil samples were taken from depths of 0-15 and 15-30 cm, and subjected to a series of preparation and analysis procedures. Initially, the soil samples were air- dried and subsequently ground to attain a fine consistency. Subsequently, the ground samples were passed through a 2 mm sieve for further soil analysis. To accurately determine the total carbon (TC) and nitrogen (N) concentrations in the soil, an additional grinding step was implemented. The soil samples were further ground to a finer consistency and sieved through a 0.25 mm sieve. To determine the inorganic carbon (IC) content, the total calcium carbonate ($CaCO_3$) content of the soil was measured using a calcimeter device of the Schibler type. The concentration of Soil Organic Carbon (SOC) was determined by subtracting the content of soil inorganic carbon from the total carbon content, following the methodology outlined in previous studies conducted by (Ortas, Akpinar and Lal, 2013; Ortas and Bykova, 2020). Finally, the total nitrogen concentration in the soil samples was measured using a carbon nitrogen analyzer device. These analytical techniques and procedures were employed to assess the SOC and total nitrogen concentrations in the soil samples as part of the study.

Chickpea plant samples were collected from an area of 1 m^2 from the center of each plot, and this was done at the same time for samples of pods, seeds, shoots, and roots. The fresh weight of the samples was measured immediately after harvesting. For determining their nutrient level, the samples were washed with distilled water and oven-dried for 72 hours at 60 °C. Then the dried samples were analyzed for total C and N concentrations using a CN elemental analyzer (Fisher-2000) by the dry combustion method. The nutrient concentrations of the plant samples were determined using ICP.

Statistical Analysis and Data Evaluation

The statistical analysis was completed using R version 4.2.2. An analysis of variance (ANOVA) was conducted to evaluate the overall effects of different fertilizers on soil properties and plant development. The least significant difference test (P 0.05) was then applied to see whether there were any significant differences between the treatment means.

RESULTS AND DISCUSSION

Effect of Organic and Inorganic Fertilizers on Chickpea Plant growth and Nutrition

Plant Biomass Production

The influence of long-term inorganic and organic fertilizers on the fresh weights of shoots, roots seeds of the chickpea plant were examined, and the findings are illustrated in **Error! Reference source not found.**. The mineral fertilizer treatment exhibited significantly higher fresh weights of shoots (17.83 t ha^{-1}), pods (8.8 t ha^{-1}), and roots (0.58 t ha^{-1}) compared to all other treatments (Figure 1).

Shoot and pod fresh weights were not significantly different between mineral and compost + AMF treatments as well. This could be the contribution of AMF to enhancing nutrient access to host plants. The substantial growth observed in plants treated with mineral fertilizers can be attributed to the high concentration of nutrients added in soluble and readily available forms (Sarret et al., 2002). The accessibility of nutrients likely facilitated the continued growth and development of chickpea plants. Nevertheless, the nutrients incorporated in manure and compost are typically present in less readily available forms for plants compared to their mineral counterparts. While manure and compost contribute to the total nutrient content, the availability of these essential nutrients for plant growth depends upon their breakdown and release from the organic constituents (Rosen and Bierman, 2005). This process of nutrient release from organic sources may take longer and is influenced by factors such as microbial activity and environmental conditions.

Nutrient Concentrations in Plant Tissues

Carbon and Nitrogen Concentration in Seed, Shoot and Root Tissue

Following harvest, the levels of carbon (C) and nitrogen (N) in various plant tissues, such as seeds, shoots, and roots, were measured. With the exception of root C concentration, none of the factors shown in Figure 2 shows any discernible changes. Between 35.41% (in the control) and 40.17% (in the compost + AMF treatment), the values for shoot C varied. Root C content varied significantly between treatments, with the mineral treatment having the highest value (49.24%) and the manure (44.06%) and compost (42.48%) treatments coming in second and third, respectively. The root C concentration was lowest in the control treatment (37.29%). Seed C contents ranged from 39.27% to 46.55% and remained largely constant between treatments.

Regarding N concentrations, the values ranged from 1.85% to 2.27% in shoot tissue, 1.43% to 3.28% in root tissue, and 4.41% to 6.17% in seed tissue. The manure treatment resulted in the highest levels of N in the roots. The compost +AFM treatment also showed the highest seed N concentrations (6.17%). These findings suggest that the addition of organic nutrient sources can enhance N accumulation in plant tissues, particularly in the root and seed tissues. The lack of significant differences in shoot and seed C and N concentrations across treatments implies that the nutrient sources and management strategies may have a limited impact on these parameters. However, the observed differences in C concentrations in the roots suggest that the treatments may have impacted the allocation patterns of C within the plant, specifically in the shoot and root tissues.

The use of organic sources resulted in higher plant N concentrations when compared to both the control and mineral fertilizer treatments. In previous works, it has been reported that organic fertilizer applications exhibited higher concentrations of nutrients in the plant

tissue compared to the control and mineral treatments. In line with this finding, Özkan, Asri, Demirtaşi and Arı (2013) also reported that various organic and inorganic fertilizers applied in greenhouse pepper cultivation led to increased N content in pepper plants relative to the control treatment. Furthermore, Chirinda, Olesen and Porter (2012) found that root C content showed higher levels in organic fertilizer-based systems for spring barley in 2008, as well as in wheat (Akşahin, Işik, Öztürk and Ortaş, 2021).

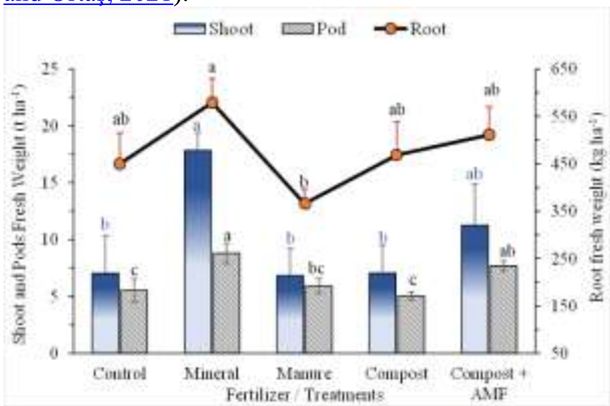

Figure 1. Effect of different fertilizer applications on fresh biomass of chickpea plant.

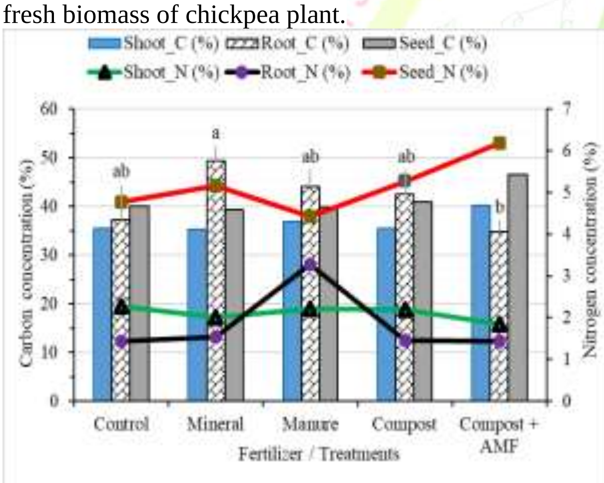

Figure 2. Effect of different fertilizer applications on C and N concentrations of plant tissues

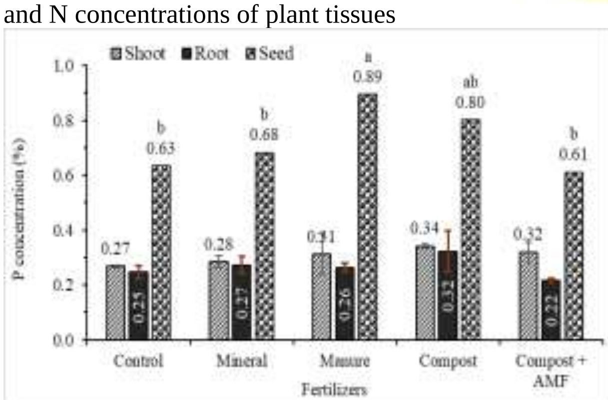

Figure 3. Effect of different fertilizer applications on P concentration in the chickpea plant tissues.

Phosphorus, Potassium and Zinc Concentrations in the Plant Tissues

The uptake of P by seed in treatments that received animal manure (0.89%) was relatively higher, though it was statistically similar to the compost treatment (Figure 3). There were no significant differences observed in the parameters for root and shoot P concentration, as indicated in Figure 3. However, the maximum shoot P concentration (0.34%) was found to be under the compost application. The same result was seen in the root, where the highest value (0.32%) was in the compost treatment.

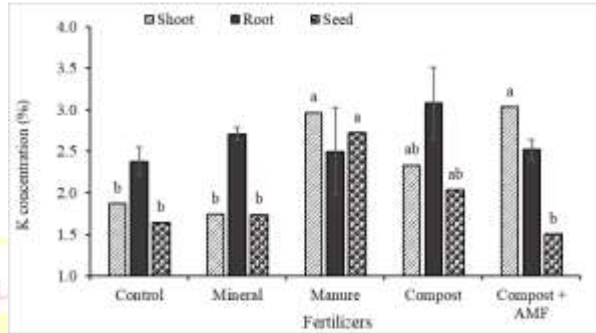

Figure 4. Effect of different fertilizer application on K concentration

Figure 4 shows that, unlike root tissue, the concentration of potassium (K) in the shoot and seed was significantly affected by fertilizer applications. The concentration of K in the seeds (2.72%) was relatively higher in treatments where animal manure was applied, and statistically did not differ from the compost treatment. The simultaneous application of compost and AFM resulted in the highest levels of K in the shoot (3.04%), which was statistically similar to the animal manure treatment (2.96%). There were no noticeable variations in root K concentrations across the different treatments. However, relatively, the maximum concentration of K in the roots (3.08%) was found when compost was applied.

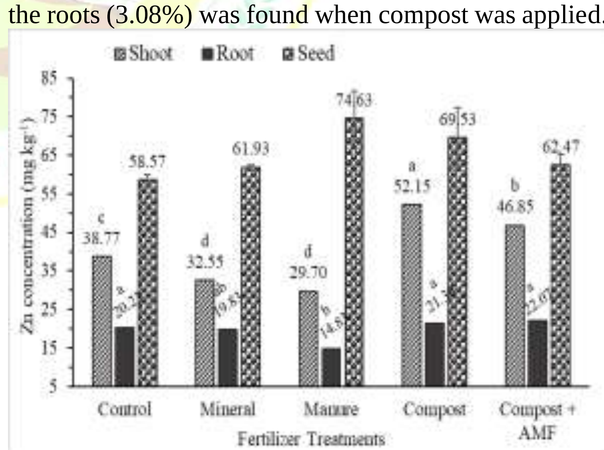

Figure 5. Effect of different fertilizer application on Zn concentration

The results presented in Figure 5 demonstrate significant differences in zinc (Zn) concentration in plant tissues, except in the seeds. Shoot Zn concentration exhibited notable variations, with the compost treatment showing statistically the highest value of 52.15 mg kg^{-1}, followed by compost + AFM (46.85 mg kg^{-1}), minerals (32.55 mg kg^{-1}), and manure (29.70 mg kg^{-1}). In the roots, no

significant variations were found between the treatments, except for the manure treatment, which was statistically the lowest (14.83 mg kg^{-1}). The compost + AFM treatment showed the highest Zn level of 22.07 mg kg^{-1} in the root. The seed Zn concentration ranged from 58.57 mg kg^{-1} (in the control) to 74.63 mg kg^{-1} (in the manure treatment), and there was no statistical difference among the treatments.

In general, the animal manure treatment showed the highest concentrations of K and P in both the shoots and seeds, whereas the compost treatment exhibited the highest concentrations of Zn in root and shoot tissue and the highest concentration of P in the root. The Zn concentration in the seed was highest under compost + AMF treatments. Nitrogen-fixing plants contain higher mineral nutrients, especially micronutrients, compared to non-N-fixing plants. Therefore, organic fertilizers resulted in higher concentrations of P, K and Zn in the chickpea plant tissues when compared to control and mineral fertilizers. These might be attributed to the presence of these nutrients in the organic materials, primarily found in their feedstock's (Li et al., 2007; Ortas, 2012a).The phosphorus and potassium content present in the organic fertilizers should be considered when calculating the application of phosphorus and potassium fertilization (Richner, Flisch, Sinaj and Charles, 2010). Many other studies, such as Kumar and Jat (2010) also found that organic fertilizers can boost plant nutrition because of their source of multiple nutrients. As a result, the improved plant growth can be credited to the enhanced availability of nutrients obtained from organic sources. AMF also enhances the absorption of nutrients with limited mobility in the soil, such as P and Zn, and this has been linked to higher nutrient content in plants, leading to increased levels of zinc in seeds (Hayman, 1982; Ortas, 2012a, b).

Effect of organic and Inorganic Fertilizers on Soil Properties

The results for the long-term influences of different fertilizers on SOC, total Nitrogen (TN), available soil P and soil C:N ratio at 0 -15 and 15-30 cm depths are presented in Table 2. The soil OC at 0-15 cm depth, soil TN at 15-30 cm depth, and soil C:N ratio and P concentration at both depths were significantly ($P< 0.05$) changed by fertilizer treatments. At the 0-15 cm soil depth, animal manure treated plots have a significantly higher soil OC of 2.05%, followed by compost treated plots (1.96%). However, at the depth of 15-30 cm, relatively higher soil OC (2.64%) was found under compost treatment, followed by compost +AMF and animal manure. Generally, there was a noticeable trend toward an increment in the soil OC in the plots receiving organic fertilizers over inorganic fertilizers. This could be attributed to the fact that the incorporation of organic materials from organic fertilizers has a greater impact compared to inorganic sources.

Furthermore, there was a slightly higher soil organic carbon (SOC) pool at a surface depth (0 to 15 cm), as compared to 15 to 30 cm depth. This might result in a lower rate of decomposition of soil OC in the sub-soil. Ortas and Lal (2014) and (Ortas and Lal, 2012) supports this explanation, suggesting that the inclusion or integration of organic materials and the presence of intact soil aggregates contribute to the preservation of SOC in deeper soil layers.

Table 2. Effect of different fertilizer application on selected soil properties

Fertilizers	Soil depth	Soil OC (%)	Soil TN (%)	C:N ratio	Available P (mg kg^{-1})
Control	0-15 cm	1.69 bc	0.133	13.05 a	2.36 d
Mineral		1.37 d	0.142	9.63 b	9.01 c
Animal Manure		2.05 a	0.192	10.66 ab	47.62 a
Compost		1.93 ab	0.180	10.74 ab	21.65 b
Compost + AMF		1.56 cd	0.133	11.71 ab	7.78 c
LSD (P<0.05)		0.30	0.025	3.10	2.36
Control	15-30 cm	1.69	0.131 b	13.00	4.17 c
Mineral		1.32	0.124 b	10.53	5.25 c
Animal Manure		1.88	0.182 a	10.04	45.28 a
Compost		2.64	0.189 a	14.13	19.00 b
Compost + AMF		1.88	0.134 b	13.81	5.81 c
LSD (P<0.05)		1.35	0.070	5.87	5.59

Means followed by the same letter are not statistically different for each depth.

Significantly, the highest soil P concentration (47.62 mg kg^{-1} at 0 to 15 cm, and 45.28 mg kg^{-1} at 15 to 30 cm depths) was found in the animal manure treatment compared to both the control and other treatments. At a depth of 0 to 15 cm, there was no significant difference between the treatments in terms of TN, whereas a notable variation was found at a depth of 15-30 cm. It has been found that animal manure (0.182 %) and compost (0.189 %) resulted in significantly higher soil TN compared to the rest of the treatments. The increased soil organic matter (SOM) in these treatments may have contributed to higher soil TN levels. Moreover, it was noted that the soil carbon-to-nitrogen (C:N) ratio was lowest (≤10) in the mineral fertilizer treatment, while it exceeded 10 in the other treatments.

Correlation Analysis

A Pearson correlation analysis was employed to evaluate the relationship between the variables, and the correlation result is indicated in Figure 6. A positive and highly significant correlation ($P<0.001$) was observed, indicating a strong association between seed K and seed P, seed Zn and Seed P, seed K and soil P at both depth, soil OC and soil TN at both depths, and soil P and soil TN (Figure 6). On the other hand, soil P at both depths had a strong negative relationship ($P<0.05$) with shoot and root Zn concentrations. The soil P level has a negative impact on Zn uptake by plants. Additionally, the SOC level significantly influences the accessibility of plant nutrients such as N and P, highlighting the importance of SOC management to enhance nutrient content in the soil.

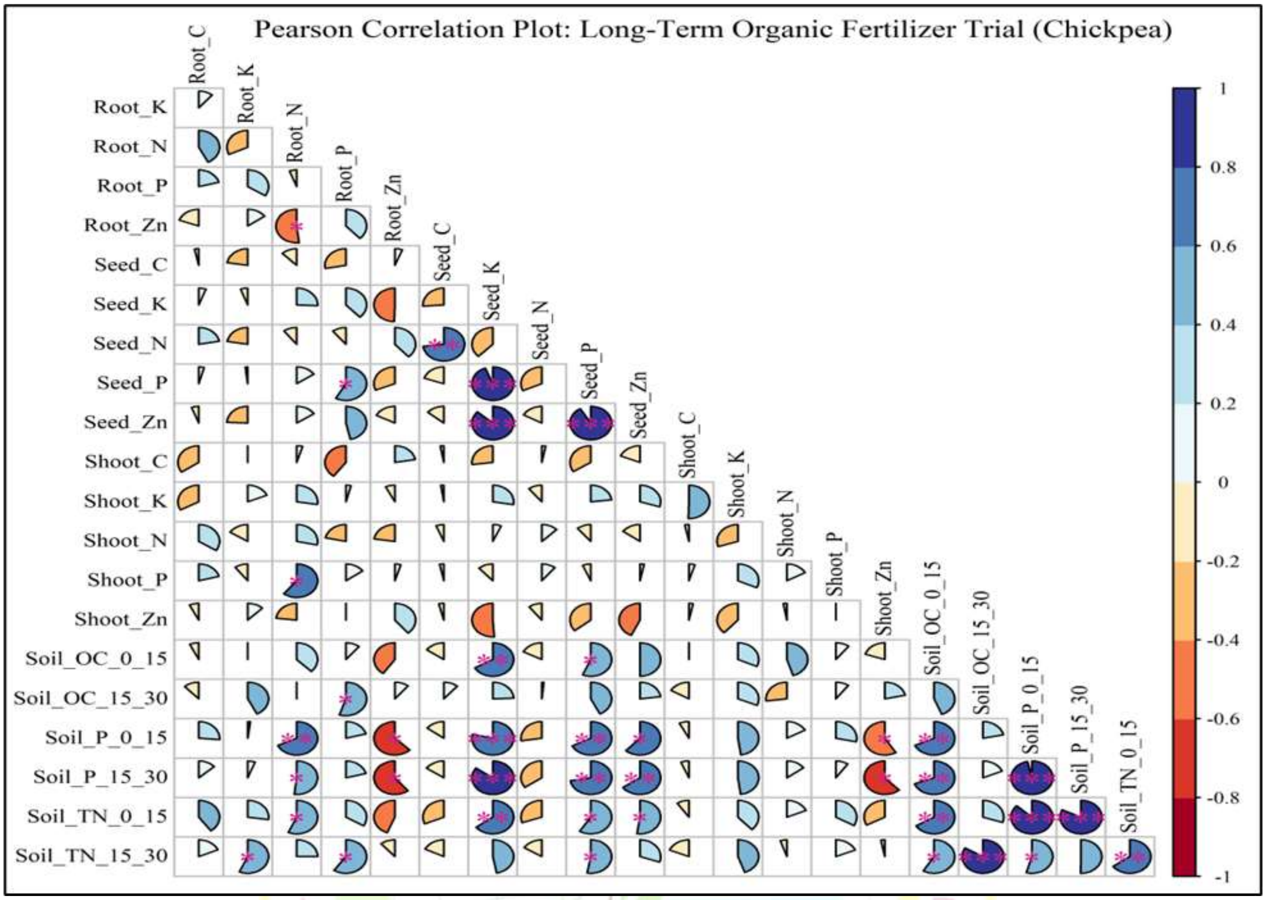

Figure 6. Correlation plot for dependent variables. The larger the circle, the stronger the associations among the variables. Deep blue colors (to top) show a strong positive correlation while deep red colors show a strong negative correlation. 0 -15 and 15 -30 are the soil sampling depths in cm.

CONCLUSION

In effect of various organic and inorganic fertilizers on the growth of chickpea plants, nutrient absorption, and the concentrations of organic carbon (OC) and nitrogen (N) in the soil were investigated. The results revealed that mineral fertilizer was the most effective in enhancing plant biomass (shoot, root, and pod) compared to other treatments. Even though maximal root N was demonstrated following manure application, the N concentrations in various plant tissues were not considerably altered. With the exception of compost + AMF, the C concentration in the roots was statistically similar across all treatments but was substantially greater in the mineral treatment. Phosphorus (P) concentrations in the roots and shoots did not differ noticeably. However, the P concentration in the seed was higher under animal manure, and statistically similar to compost. The plant tissues exhibited higher K and P concentrations, but a lower Zn concentration when treated with animal manure.

The fertilizer treatments also affect the soil's properties. Animal manure treatment resulted in significantly higher SOC and total nitrogen (TN) concentrations compared to other treatments. Organic fertilizers contributed to increased soil OC and TN, while mineral fertilizers had a lower carbon-to-nitrogen (C:N) ratio. These findings point out the potential of organic fertilizers to improve soil quality and its nutrient levels, contributing to sustainable agriculture. In conclusion, the use of mineral fertilizers has led to a significant and visible increase in plant biomass, while the use of animal manure has led to higher concentrations of OC, N, and P in the soil. These results advance knowledge of how soil nutrients and chickpea growth are affected by organic and inorganic fertilizers. To maximize their potential, more research is required on the carbon footprint, economics, and environmental sustainability of these fertilizer treatments.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

Effect of potting mixture on growth and development of quality planting material of *Bambusa balcooa.*

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ABSTRACT
An experiment was conducted to find a suitable pot mixture for improving the vigor of the saplings in *Bambusa balcooa*. Pot mixture containing garden soil + FYM in 1:1 ratio recorded the maximum seedling height (93.75 cm), number of branches (3.25), base diameter (7.50 mm), no. of internode (8), internode distance (11.25 cm) and weight of tiller (119.50 gm)
Keywords: Bamboo, *Bambusa balcooa*, neemcake, poultry manure and Vermicompost.

INTRODUCTION

Bamboo is one of the important forest species used in paper industry, house construction, ornaments making *etc*. Most of the bamboo species are propagated both by seeds and vegetative means. *Bambusa balcooa* is mainly multiplied by seeds, culms, rhizomes *etc.* The seedlings in the nursery usually vary in vigor and other growth characters. Therefore, production of good quality seedlings is an important step for ensuring uniform plantation. Seedling quality can be improved

Nursery through utilizing proper container and media mixture. Many researchers reported the increased seed germination (Bahuguna *et. al.*, 1989; Vanangamudi *et. al.*, 1993; Biradar *et. al.*, 1998) and seedling vigor (Maronek *et. al.*, 1980; Young, 1990) in the forest species due to the use of the nursery mixture. However, the information on use of the nursery mixture with suitable organics for *Bambusa balcooa* is limited. Hence, the present study was aimed to find out the suitable nursery mixture for the production of more offsets for vegetative propagation or forest planting through seed propagation in *Bambusa balcooa* species.

MATERIALS AND METHODS

The nursery pot mixtures were prepared by using different media and manure as per the following details. The Treatments are T_1- Garden soil alone; T_2- garden soil + Cocopit (1:1); T_3- garden soil + FYM (1:1); T_4- garden soil + Vermicompost (1:1), T_5- cocopit + FYM (1:1), T_6- garden soil + neem cake (1:1), T_7- garden soil + poultry manure (1:1), The different nursery mixtures were filled separately in the polythene bags (8 x 12 Inch) in four replications comprising of 25 bags in each replication by following the completely randomized design. The bamboo saplings having a height 25 cm are planted in polythene bags filled with different potting mixtures and watered regularly for the proper growth of saplings. The survival per cent and other growth characteristics were recorded six months after planting. The data were analyzed using the statistical method described by Panse and Sukhatme (1967) and the critical difference values were calculated at 5% probability level.

RESULTS AND DISCUSSION

The saplings in the nursery will vary in vigour and other growth characters. It is important that only vigorous seedlings are selected for planting (Farooqi and Sreeramu, 1999). The vigour of the saplings is highly influenced by the nursery pot mixtures. In the present investigation, the results showed that the treatment T_3 recorded significantly maximum height (93.75 cm) of tillers in potting mixture of garden soil + FYM (1:1) as compared to other treatment. It was followed by treatment T_4 (garden soil + Vermicompost (1:1). Whereas, lowest height (38.75 cm) of tillers was recorded in garden soil + cocopit potting mixture (1:1). Similar results of pot mixture containing soil: sand: Vermicompost / soil: sand: goat manure gave higher germination and vigorous seedlings in *Albizia lebbeck* (Natarajan, 1999) and arecanut (Raja *et al.*, 2002). Raja *et. al.*, (2012) also recorded maximum height of *Bambusa tulda* saplings in soil + sand + Vermicompost potting mixture (2:1:1).

Table: 1. Growth characteristics of *Bambusa balcooa* saplings in different potting

Treatments	Initial sapling height (cm)	Height of tiller (cm)	No, of branches	Base diameter (mm)	No. of internode	Internode length (cm)	New tillers	Total no. of tillers	Weight of tiller (gm)
Garden soil (100 %)	25	52.00	1.00	4.00	6.75	7.50	0.00	1.00	24.56
Garden soil + Cocopit (1:1)	25	38.75	1.00	2.50	4.50	4.75	1.00	2.00	17.75
Garden soil + FYM (1:1)	25	93.75	3.25	7.50	8.00	11.25	1.00	1.75	119.50
Garden soil + Vermicompost (1:1)	25	80.00	1.75	5.75	7.75	9.75	0.75	1.75	63.75
Cocopit + FYM (1:1)	25	48.75	2.00	3.25	6.00	8.00	1.75	2.75	50.50
Garden soil + Neemcake (1:1)	25	44.00	2.00	2.75	5.50	7.75	1.25	2.50	33.75
Garden soil + Poultry manure (1:1)	25	57.75	2.00	4.25	7.00	9.50	1.00	2.00	39.75
F test		*Sig*	*Sig*	*Sig*	*Sig*	*NS*	*NS*	*NS*	*Sig*
SE +		3.11	0.30	0.59	0.66	1.28	0.41	0.45	4.36
CD @ 5%		9.31	0.89	1.78	1.98	--	--	--	13.07

Significantly maximum number of branches was recorded in treatment T_3 (3.25) in comparison to other treatments. The base diameter was high (7.50) in the treatment T_3 (garden soil + Vermicompost (1:1). The next best treatment *viz.*, T_4 (garden soil + Vermicompost (1:1) produced 5.75 number of branches which had no significant difference with previous treatment. Gardem soil + cocpit (2.50) and garden soil + neemcake (2.75) recorded minimum number of branches during six months after transplanting of tiller (table1). Among the treatments, the maximum number of internode per tiller (8.00) and internode distance (11.25 cm) was recorded in treatment T_3 (garden soil + Vermicompost (1:1) These characters was least recorded in treatment (T_2 : Garden + cocpit (1:1), respectively. No significant difference was observed in regards with new tillers and total number of tillers amongst the different treatments. Significantly maximum weight of tillers (119.50 gm) was reported in treatment T_3 (garden soil + FYM (1:1). It was followed by treatment T_4 (garden soil + Vermicompost (1:1). Whereas, lowest weight of tiller (17.75 gm) was reported in potting mixture of garden soil + cocopit (1:1). The significant growth characteristics *viz.*, height of tillers (cm), number of branches, base diameter (mm), number of internodes, internodal length and weight of tillers was recorded maximum in potting mixture contacting garden soil with FYM and Vermicompost. Sreekrishna Bhat, (1999) found that the vermicompost acts as a good pot mixture because it contains rich nitrogen (1.5-2.5%), phosphorus (0.9-1.7%), potassium (1.5-2.4%), Magnesium (0.2-0.3%), calcium (0.5-1.0%), sulphur (0.4-0.5%) and vitamins. It also has growth hormones like gibberellins, which regulate the plant growth. It can supply full requirement of micronutrients and enhances the availability of both native and added micronutrients in soil (Purakayastha and Bhatnagar, 1997). The farmyard manure has 0.5 % nitrogen, 0.2% phosphorous and 0.5 % potassium which are slightly higher in poultry manure (3.03% N, 2.63% P, and 1.4 % K) (Sankaranarayanan, 2004). This might be the reason for enhanced performance in bamboo seedlings. The increased nutrient level in poultry manure might be the cause of the seedling vigour improvement in the bamboo after the Vermicompost treatment. The Vermicompost has the additional nutrients and vitamins other than nitrogen, phosphorous and potassium which showed positive effect on the seedling vigour. The other treatments including cocpit, neemcake had no significant effect on the performance of the seedlings.

Fig 1. Effect of the potting mixture on tillers of bamboo

CONCLUSION

It is concluded that the pot mixture comprising of soil + FYM (1:1) have recorded the maximum height of tiller, number of branches, base diameter, number of internode, internodal length and weight of tiller. Therefore, this pot mixture can be recommended for getting the vigourous seedlings through saplings propagation. Maximum number of offsets produced can also be separated for further vegetative propagation or planting.

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CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

Laboratory management of *Sclerotium rolfsii* pathogen by different test to check the efficacy of plant products, biocontrol agents and fungicides.

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ABSTRACT
Eight bioagents and eight botanicals eleven treatment of each of them were evaluated in a laboratory environment and the results showed that all of the fungicides strongly suppressed *S. rolfsii* mycelia growth compared to the untreated control. Azoxystrobin, Hexaconazole, Penconazole, Propiconazole, and Carbendazim+Mancozeb showed the highest mycelia growth suppression (100%) and were followed by Carbendazim (96.60%). In case of bioagents, *Trichoderma viride* had the highest mycelial growth inhibition in bioagents (69.62%), followed by *T. harzianum* (66.66) and in terms of botanicals, *Zingiber offcinalis* (83.34%) was the botanical that considerably inhibited mycelial growth mostly, followed by *Allium sativum* (85.64).
Keywords: Propaconazole, *T. viride*, Botanicals, Efficacy test, *Cicer arientum*.

INTRODUCTION

One of the most significant pulses (Rabi) crops in India rainfed farming method is gram cultivation (*Cicer arietinum* L.). Both human intake and animal nutrition involve its utilisation. It is eaten fried, boiled, or both cooked and eaten. Husks and leftover dal pieces make excellent livestock feed. As a vegetable, fresh green leaves are utilised. For the preparation of various desserts, gramme flour is employed. It has therapeutic value as well. In addition to being rich in Ca, Fe, and Nicin, it has 21.1 percent protein, 61.5 percent carbs, and 4.5 percent fat. Its leaves exude malic acid, which is found in amounts ranging from 90 to 95 percent, along with oxalic acid, which is found in amounts ranging from 5 to 10 percent. The grains are available in markets in developed nations either dry or tinned for everyday use in soups, vegetable medleys, or as a component of fresh salads. Moreover, grains are utilised as vegetables. Besan, also known as dehusked gramme flour, is frequently used to make pakodas, kadhi, namkeens, and other snack foods. The chickpea is cultivated all throughout the world. Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Rajasthan, Andhra Pradesh, Karnataka, and Maharashtra are among the Indian states where it is widely grown. It is primarily grown on a variety of soils with varied levels of residual moisture under rainfed conditions. More than 50 diseases can affect the chickpea crop (Nene et al. 1981). In addition to other diseases, the wilt (*Fusarium oxysporum*) f.sp *ciceri*, root rot [RR] (*Rhizoctonia bataticola*), and collar rot [CR] (*Sclerotium rolfsii*) that appear annually in the Marathwada region of Maharashtra have also become a limiting factor for the cultivation of chickpeas in many states of the nation. Farming faces a serious difficulty caused by fungi that cause Chickpea wilt complex (CWC). Researchers have noticed the CWC, which causes mortality rates ranging from 0% to 100%.

For the control of diseases, new fungicide chemical compounds are required. Contrarily, using biological management measures to manage soil-dwelling fungi is more cost-efficient, safer, and effective. Given the significance of the CWC, the current investigations were conducted to determine the effectiveness of novel chemical fungicides and other biocontrol agents for the management of CWC (wilt, RR, and CR). Particularly in the wet environment of the Indian subcontinent, chickpea is a significant pulse crop of the semi-arid tropics. This crop has seen an export-driven expansion in recent years in new riches like Australia and Canada. It is grown in India on an area of roughly 10.22 million hectares, producing 9.88 million tonnes at a yield of 967 kg per hectare. In Maharashtra, chickpea production in 2013–14 total 16.22 L tonnes, with an area under cultivation of 18.19 L ha. In Marathwada, the area planted with chickpeas in 2013–14 was 6.58 L.ha, and the crop produced 6.64 L. tonnes with a productivity of 918 kg/ha (Research work report on pulses of Agricultural Research Station, Badnapur 2014-15).

Wheat, mustard, lentils, and other crops are produced alongside or in addition to chickpeas. A number of air, soil, and seed-borne illnesses have an impact on it and lower its output. Some of these illnesses are brought on by soil-borne infections such *R. bataticola*, F. *oxysporum* f.sp *ciceri*, and *S. rolfsii* (CR). CR is one of these diseases that is growing more dangerous at the seedling stage, particularly in areas where paddy or soybean-based cropping systems are practised. Plant mortality in India ranges from 54.7% to 95%. The pathogen significantly reduced the population of plants with a diverse host range (Aycock, Punja, 1988). The pathogen *S. rolfsii* (Sacc.), which causes CR, is widely known for being polyphagous, widespread, and non-target. It is one of the most harmful soil-dwelling pathogens and causes significant crop loss (Azhar Hussain et al., 2006). The damaged area of potato plants and tubers displayed the distinctive white, radiating, and profuse mycelial development of *S. rolfsii*. On the mycelial mat, a significant number of sclerotial initiations were seen. Sclerotia, which appeared on the affected portions and initially had a white colour before turning chocolate brown, were spherical or ellipsoidal in shape and ranged in diameter from 0.5 mm to 2.5 mm. The disease known as CR, which is brought on by *S. rolfsii* Sacc., is one of the biotic reasons causing reduced chickpea yield. Good soil moisture, high soil temperature (25–30ºC), and little organic matter in the soil all favour the illness (Mathur & Sinha, 1968). Between 55 and 95 percent of chickpea seedlings can die from CR (Gurha & Dubey 1982). The existence of vulnerable hosts, a sufficient inoculum of virulent pathogen isolates, and climatic circumstances that favour disease development over time are some of the variables that contribute to a severe outbreak of the disease. The pathogen *S. rolfsii* has a wide host range, prolific proliferation, and the capacity to create chronic sclerotia that cause significant economic losses (Mordue, 1974). There may be free *S. rolfsii* Sacc. sclerotia in the soil or sclerotia associated with plant waste (Aycock and Punja, 1985). Sclerotia spreads through human activity (dirty tools and soil), infected transplant seedlings, water (through irrigation), wind, and perhaps seeds. Like other fungi that produce sclerotia, this one produce distinct sclerotia and sterile mycelia. Sclerotium was the name given to those with small, internally distinct, spherical sclerotia that ranged in colour from tan to dark brown to black (Punja and Rahe 1992). The teleomorphic condition, however, was later found (Punja 1988), proving that the fungus is a member of the basidiomycete class.

The best and most practical way to control the disease is to cultivate resistant cultivars, and sources of resistance to this disease have been found in many different nations (Sugha et al., 1991; Gurha et al). The frequency of virulent *S. rolfsii* isolates prevented the development of stable resistance. Previous researchers had shown that *S. rolfsii* populations varied geographically (Harlton et al., Nalim et al., 1995; Okabe et al., 1998). Understanding sclerotium development, mycelial compatibility, and sensitivity were the studies main goals. Hence, there is great potential to increase chickpea yield by reducing losses brought on by biotic factors like CWC. The study was conducted with the aim of managing the disease by biological agents and fungicides, taking into consideration the relevance of the illness, the socioeconomic position of the crop, and the insufficient scientific work carried out on the disease in the state.

MATERIALS AND METHODS

Laboratory test of fungicides

By employing the Poisoned food technique [PFT] (Nene and Thapliyal, 1993) and utilizing potato dextrose agar (PDA) as the primary culture medium, the effectiveness of 11 fungicides against *S. rolfsii* was assessed in lab at various three replications. To achieve the desired replication, the necessary quantity of each test fungicide was determined based on active component and well mixed with autoclaved and cooled (40ºC) PDA medium in conical flasks (250 ml/cap). After that, 20 ml of fungicide-added PDA medium was aseptically placed into Petri plates (90 mm in diameter) and left to solidify. A triple set of Petri plates, treatments, and replications were kept for each test fungicide and its test replication. Just after medium had solidified, each plate was individually injected aseptically with a 5 mm culture disc taken from a week-old, actively growing pure culture of *S. rolfsii* using a cork borer. The Petri plate was incubated at 27 + 1 ºC with the culture disc positioned in the centre of PDA in a reversed configuration. Petri dishes containing plain PDA (with no fungicide) was separately inoculated with the *S. rolfsii* culture disc and kept as control treatment.

Treatment details

Employing the PFT (Nene and Thapliyal, 1993) utilising PDA as the basal medium, it will be investigated how different fungicides affect the growth of *S. rolfsii* with treatment details as Design: CRD, Three replications, twelve treatments. The eight treatments were used when fungal antagonists were tested *in vitro* against *S. rolfsii* using the dual culture technique [DCT] (Dennis and Webster, 1971). The test pathogens (*S. rolfsii*) and test bioagents were grown in cultures for the investigation using material that was seven days old. The fungus culture development and bioagents were taken out of PDA discs (5 mm in diameter) using a sterilised cork borer. The test pathogen and bioagent were then deposited in pairs on two culture discs, one of each, and aseptically positioned exactly opposite of one another on solidified PDA media in Petri plates. The plates were then incubated at 27 + 1 ºC. Petri plates, treatments, and replications were all kept in triplicate. PDA plates with simply the test pathogen culture disc as an inoculum were kept as the untreated control. Whereas in the case of botanicals, plant species believed to have potential antifungal and therapeutic effects (Alice, 1984) on fungal pathogens and to be available locally were

gathered from the College of Agriculture, Badnapur farms and nearby areas. Eight plant species and botanicals that were locally accessible were employed in the trials. Table 2 lists all of the treatments in order as fungicides, bioagents, and botanicals, respectively. Using Vincent (1927) formula, the percentage of mycelia inhibition of growth of the test pathogen over the untreated control was computed. The per cent Inhibition (I) is equal to C-T divided by C X 100. Where, C is the growth (mm) of test fungus in untreated control plate and T is the growth (mm) of test fungus in treated plates.

RESULTS AND DISCUSSION

Evaluation of several fungicides *in vitro*

Observations on the effect of various eleven fungicides on the inhibition of pathogen mycelial development on PDA are shown in Table 1, which showed that *S. rolfsii* growth varied greatly as a result of the use of various fungicides. Azoxystrobin, Hexaconazole, Penconazole, Propiconazole, and Carbendazim + Mancozeb all showed the greatest mycelia growth suppression (100%); Carbendazim came in second (96.60%). Metalaxyl showed the highest level of inhibition (93.20%), followed by Mancozeb (69.56%), Copper oxychloride (56.85%), and Captan (44.87%). Thiram lowest percent of inhibition was 37.12%, which was likewise noticeably better than control. An earlier study found that fungicides had comparable fungistatic effects against *S. rolfsii*, which causes collar rot in numerous crops including chickpea (Sahu et al., 1990; Tiwari et al., 1995; Alam et al., 2004; Tripathi and Khare et al., 2006; Banyal et al., 2008 and Gour and Sharma 2010).

Evaluation of several bioagents *in vitro*

Table 1 shows the findings on the mycelial growth and inhibition of *S. rolfsii* using 7 fungal and 1 bacterial antagonist. The test pathogen showed the least linear mycelial growth (27.33 mm) and the highest mycelial inhibition (69.62%) of the eight bioagents examined, with *T. viride* being the most effective. *T. harzianum* and *T. hamatum*, which respectively recorded mycelial development of 30 mm and 36.67 mm of the test pathogen with inhibition of 66.66 and 59.25 percent, were the second and third best antagonists. *T. koningi* (col. dia.: 40 mm of test pathogen and inhibition: 55.55%) and *T. longibrachiatum* (col. dia. 44.33 mm of test pathogen and inhibition: 50.73%) came in second and third, respectively. The bacterial antagonist *P. fluorescens* was shown to be least effective, inhibiting mycelial growth of *S. rolfsii* by 28.88% while only causing a 26 mm colony growth of the latter.

The current study findings on the effect of bioagents on *S. rolfsii* mycelial growth are consistent with those previously reported by a number of researchers (Prasad and Rangeshwaran, 2001; Singh et al., 2003; Sharma et al., 2007; Kumar et al., 2008 and Reddy et al. 2011).

Evaluation of several botanicals *in vitro*

As shown in Table 1, *S. rolfsii* mycelial growth inhibition at 10% ranged from 22.34% (*Eucalyptus* sp.) to 85.64% (*Allium sativum*). *A. sativum*, however, significantly inhibited mycelial growth the most (85.64%), followed by *Zingiber offcinalis* (83.34%), *Curcuma longa*, *Azadiracta indica*, *Ocimum sanctum*, *Parthenium histeropous*, and *Lantana camera*, while *Eucalyptus* spp., among plant extract treatments, showed the least amount of inhibition (22.34%).

Several workers have previously reported that the test botanicals had a similar impact against S. rolfsii infecting chickpea and *S. rolfsii* infecting several other crops. Several researchers have previously reported that certain plants, including ginger, garlic, neem, turmeric, parthenium weed, nilgiri, and ghaneri, significantly inhibited the mycelial growth of *S. rolfsii* (Shivapuri et al., 1997; Seshakiran, 2002; Khanzada et al., 2006; Kulkarni, 2007; Singh et al., 2007; Suryawanshi et al., 2007; Patil and Raut, 2008; Mundhe et al., 2009; Farooq et al., 2010; Sultana et al., 2012).

Table 1. *In vitro* effect of fungicides, bioagents and botanicals on mycelial growth of *S. rolfsii*

Fungicides

Sr. No	Treatment	Conc. (ppm)	Colony Dia. of test pathogen (mm)	Per cent inhibition
T_1	Captan (50 %WP)	2500	49.00	44.87 (26.68)
T_2	Copperoxy chloride (50% WP)	2500	38.33	56.85 (34.71)
T_3	Mancozeb (75 %WP)	2500	27.00	69.56 (44.32)
T_4	Metalaxyl (25% WP)	2500	06.00	93.20 (69.39)
T_5	Thiram (75% WP)	2500	46.00	37.12 (21.98)
T_6	Azoxystrobin (23% SC)	1000	00.00	100 (89.98)
T_7	Carbendezim (50 %WP)	1000	03.00	96.60 (75.40)
T_8	Hexaconazole (5% EC)	1000	00.00	100 (89.98)
T_9	Penconazole (10 %EC)	1000	00.00	100 (89.98)
T_{10}	Propiconazole (25% EC)	1000	00.00	100 (89.98)
T_{11}	Carbendezim + Mancozeb (75% WP)	1000	00.00	100 (89.98)
T_{12}	Control	--	89.00	00.00 (0.00)
	S.E. $\pm$		1.83	2.49
	C.D. at 1%		5.35	7.26

Bioagents

Tr. No.	Treatment	Colony Dia. of bioagent * (mm)	Colony Dia. of test pathogen * (mm)	Per cent inhibition
T_1	*Aspergillus flavus*	39.00	51.00	43.33 (25.67)
T_2	*Aspergillus niger*	42.00	48.00	46.66 (27.82)
T_3	*Pseudomonas fluroscence*	26.00	64.00	28.88 (16.79)
T_4	*T. hamatum*	53.33	36.67	59.25 (36.34)
T_5	*T. harzianum*	60.00	30.00	66.66 (41.80)
T_6	*T. koningi*	50.00	40.00	55.55 (33.75)
T_7	*T. longibrachiatum*	45.67	44.33	50.73 (30.49)
T_8	*T. viride*	62.67	27.33	69.62 (44.14)
T_9	Control	0.00	90.00	00.00 (00.00)
	SE ±	1.21	1.21	0.91
	C. D . at 1%	3.61	3.61	2.71

Botanicals

Tr. No.	Treatment (Botanical Names)	Conc. v/v (%)	Colony Dia. of test pathogen * (mm)	Per cent inhibition
T_1	*Allium sativum*	10	12.67	85.64 (59.02)
T_2	*Azadiracta indica*	10	30.67	65.10 (40.66)
T_3	*Curcuma longa*	10	25.67	70.82 (45.15)
T_4	*Eucalyptus sp.*	10	68.33	22.34 (12.90)
T_5	*Lantana camera*	10	65.67	25.38 (14.70)
T_6	*Ocimum sanctum*	10	42.67	51.46 (30.99)
T_7	*Parthenium histeropous*	10	61.33	30.33 (17.65)
T_8	*Zingiber offcinalis*	10	14.67	83.34 (56.55)
T_9	Control (Untreated)		88.00	0.00 (0.00)
	SE ±	1.57	1.45	
	C.D .at 1%	4.66	4.30	

*Mean of three replications, Dia. Diameter, Figures in Parentheses are arc sin values.

CONCLUSION

All of the fungicides tested in vitro were proven to be antifungal and fungistatic against *S. rolfsii*. Nevertheless, Azoxystrobin, 23% SC, one of the tested fungicides Penconazole (10 EC), Hexaconazol (5 EC), and Propiconazole (25 EC) M45 Mancozeb 75% WP was the most efficient treatments were Captan 50% WP and Copper Oxychloride 50% WP. When bioagents were tested in vitro, *T. viride*, *T. harzianum*, *T. hamatum*, *T. koningi*, and *T. longibrachiatum* were the most effective potential antagonists against *S. rolfsii*. All 8 botanicals examined in vitro and their aqueous extracts were proven to be fungistatic or antifungal to *S. rolfsii*. *Allium sativum* (garlic), *Zingiber officinalis* (ginger), *Curcuma longa* (turmeric), *Azadiracta indica* (neem), and *Ocimum sactum* were the botanicals with the greatest promise (Tulsi).

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CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

Yield and Nutrient Contents of Wheat, and Changes in Selected Soil Properties after 23 Years of Phosphorus Fertilizer Application

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ABSTRACT
Effective nutrient and fertilizer management practices play a pivotal role in sustaining agriculture and mitigating the effects of climate change. These practices have a direct influence on soil fertility and crop productivity. This study investigated the long-term impacts of different phosphorus (P) fertilizer doses (0, 50, 100, and 200 kg P_2O_5 ha^{-1}) on biomass yield and grain nutrient levels of wheat crops as well as on selected soil properties. The experiment was established in 1998 at the Research Center of Cukurova University in Adana, Southern Turkey. The wheat seeds were sown in October 2020 and harvested in May 2021. The experimental design was a randomized complete block, comprising 12 plots and replicated three times. Soil samples were collected at depths of 0-15 cm and 15-30 cm and subsequently analyzed for total carbon, organic carbon (OC), total nitrogen (TN), and the number of mycorrhizal spores. At harvest, wheat plant samples were collected for evaluating total dry biomass, grain yield and concentrations of potassium (K), zinc (Zn), total carbon (C), and total nitrogen (N) in the grain. The result showed that there was a linear increase in the total dry biomass of wheat, however, grain yield started to decline at P200. The wheat grain nutrient concentrations did not differ significantly across P doses, except for higher concentrations of Zn and K at P50 and higher values of grain C and N at P100. However, there was a linear decrease in Zn concentration as the applied P dose increased. The soil OC and soil TN at 0-5 cm were significantly changed relative to the control. The highest levels of soil OC and TN were observed at P100. The number of mycorrhizal spores did not significantly change with the P dose, but a decreasing trend was observed at higher doses. In conclusion, based on the observed parameters of wheat grain yield, total biomass production, grain nutrient concentrations, and soil OC storage, the application of 100 kg P_2O_5 ha^{-1} outperforms other P doses. However, the agronomic efficiencies, soil nutrient balance, and environmental effects of the applied P dose require more research.
Keywords: Phosphorus, Long-term Field Trial, Wheat, Soil Organic Carbon, Biomass Yield, Mycorrhizae.

INTRODUCTION
Agriculture, food security, and climate change are linked and have an impact on one another. The agricultural sectors contributes to climate change by releasing greenhouse gases, which in turn, impair crop production and food security (Malhi, Kaur and Kaushik, 2021; Yohannes, 2016). Effective nutrient and fertilizer management is vital for addressing climate change and the interconnected challenges (Whitmore *et al.*, 2012). Avoiding excess nutrient applications such as phosphorus (P) and nitrogen (N), can contribute to climate change mitigation. Phosphorus fertilizers have been used to improve crop yield since the first “Green Revolution” (Sahrawat, Abekoe and Diatta, 2001). However, efficient management of P fertilizer is crucial as the P reserves are being depleted (Childers, Corman, Edwards and Elser, 2011). In the soils of the Mediterranean region, including southern Turkey, limited availability of P has necessitated the implementation of extensive fertilization practices to maximize crop productivity (Ortas and Akpinar, 2011). These practices have raised environmental concerns and socio-economic issues relating to the rising cost of chemical fertilizers.

Extended P fertilization in wheat cultivation has diverse impacts on crop yield and grain quality. Saha, Saha, Murmu, Pati and Roy (2014) reported a positive association between yield and P application rate in a 40-year-old long-term field experiment. In contrast, some other studies showed that prolonged P application does not necessarily enhance yield, but does cause a

considerable rise in soil P levels (Takahashi and Anwar, 2007). In addition, the P application affects the grain nutrient concentration through its effect on their absorption and translocation. For instance, increasing the application dose of P fertilizer above 50 kg P_2O_5 ha^{-1} was reported to reduce grain zinc concentration (Zhang *et al.*, 2015).

Maintaining optimal soil fertility (quality) can support plant growth while reducing reliance on external inputs. Soil organic carbon (OC) plays an essential role in the sustainable maintenance of soil quality and the proper functioning of agroecosystems (Ramesh *et al.*, 2019). Achieving effective soil OC management requires attention to soil management, agronomic practices, and nutrient application. To facilitate carbon storage in the soil, it is essential to nourish plants with essential nutrients such as P. This enables plants to enhance photosynthesis efficiency, leading to increased CO_2 absorption and the deposition of organic materials into the soil (Himes, 1997; Lal, 2004). Therefore, the dynamics of soil OC and soil N are impacted by how P fertilizer is managed (Işık, Öztürk, Akşahin, Demirkol and Ortaş, 2020; Ortas and Bykova, 2020). Phosphorus also affects the symbiotic relationship between host plants and mycorrhizal fungi; as a higher P level reduces the infection rate and sporulation of the mycorrhizae (Ortas, 2012).

A long-term field trial is needed to better understand how P fertilizer affects wheat productivity, grain qualities, soil OC, and total N dynamics, as well as mycorrhizal fungi abundance. Despite these facts, there is limited information about the specific patterns and extent of these parameters' responses to prolonged P application (Ortas and Islam, 2018). Therefore, this study was conducted to evaluate the long-term (over 23 years) effects of different P fertilizer application rates on: (1) the total biomass yield and grain nutrient levels of the wheat crop; and (2) the changes in selected soil properties (soil OC, total N, and indigenous mycorrhizal spore counts).

MATERIALS AND METHODS

Description of Experimental Site

A long-term field experiment was established in 1998 and continued through 2020/21 (23 years) at Cukurova University agricultural research center, department of Soil Science and Plant Nutrition site. The site is situated in the Mediterranean region of Southern Turkey, at 37.0133° Latitude and 35.3587° Longitude, with an elevation of 31 meters above sea level. The area has a Mediterranean climate type, with a long-term average annual temperature of 19.1°C, and precipitation of 670.8 mm. The main rainy season is between November and April. The soils of the study area have a clay textural class with 53.5% clay, pH (7.57), organic matter (0.89%), available P (15.35 mg kg^{-1}), and total N (0.09%).

Design of Experiment

The experimental design was a randomized complete block design (RCBD) with four doses of phosphorus, such as 0, 50, 100, and 200 kg P_2O_5 ha^{-1}. These doses were labeled as P0, P50, P100 and P200, respectively. The experiment had three blocks and 12 plots, each with a 200 m2 area (20 x 10 m). Wheat seeds (Adana-99 variety) were planted in October 2020 and harvested in May 2021. Triple superphosphate (TSP) was used as a source of P fertilizer, and all P doses were applied as a basal application by broadcasting.

Data Collection and Lab Analysis

During harvesting, plant samples from a 2x1 m^2 area were collected to measure the above- and below-ground dry biomass and grain nutrient concentrations of wheat crop. Soil samples were also taken at 0-15 and 15-30 cm soil depths to determine the organic carbon, total nitrogen, C:N ratio, and number of mycorrhizal spores. The soil inorganic carbon was estimated from a $CaCO_3$ value that was determined by Calcimeter. The difference between total carbon and inorganic carbon was used to determine the soil organic carbon. The soil C:N ratio was also calculated as the ratio of soil OC to soil total N. The total carbon and nitrogen for both soil and grain samples were analyzed by the dry combustion method using Fisher CN-2000 analyzer. Using ICP, the DTPA extraction method (Lindsay and Norvell, 1978) was used to determine the amounts of K and Zn in the grains.

Statistical Analysis

The wheat crop and soil data were checked for conformity with the assumptions of ANOVA using Shapiro-Wilk's test for normality and Levene's test for homogeneity of variance. Data analysis was conducted using R programming version 4.3.0 statistical software (R Core Team, 2023). For comparing treatment means, the Least Significant Difference (LSD) test ($P < 0.05$) was employed.

RESULTS AND DISCUSSION

Dry Biomass Yield of Wheat Crop as Affected by P Application Doses

Phosphorus fertilizer has a promising positive effect on the growth and productivity of wheat crops particularly in cases where the initial soil P level is low. However, its long-term application is expected to have an impact on the nutrient stoichiometric balance and the efficiency of nutrient utilization, thereby affecting crop yield. The current study found that prolonged application of P had a significant impact on the dry biomass and grain yield of wheat (Figure 1).

The highest and lowest total dry biomass of 13.51 t ha^{-1} and 6.86 t ha^{-1} were obtained at P200 and at control, respectively (Figure 1). The applied P doses showed a significant increase in total biomass production relative to P0; however, no significant differences were observed among the various doses. Compared to the control, P50 and P200 resulted in significantly higher straw and total dry biomass production, whereas P100

and P200 showed significantly higher grain yield and root biomass. The higher total dry biomass at P200 was attributed to higher straw biomass. The grain yield obtained at P100 dose was 15% higher than at P50 and 4% higher than at P200. Consequently, applying higher P doses beyond P100 did not improve yield but increased straw biomass and reduced the harvest index. In the previous studies conducted in 2013/14 (Akpinar and Ortas, 2023) and in 2016/17 (Bykova, 2018), similar trends were observed in yield and total biomass production, except for higher grain yields recorded at P200.

The soils of the study area are known for their higher lime and clay content and moderate P fixation capacity (Ortas and Akpinar, 2011). Increasing continuous P availability through fertilizer application may contribute to the observed increase in yield and biomass production. In support of this study, Tang, Li, Ma, Hao and Li (2008) also found that wheat yield increased with P dose in a long-term (15 years) P fertilization trial. The yield reduction at the maximum P dose may be attributed to long-term P accumulation in the soil, leading to reduced crop responses to subsequent P applications. Similar research findings also indicate that long-term application of higher doses of P did not significantly improve grain yield but increased the residual soil P level (Liu, Hu, Yang, Abdi and Cade-Menun, 2015).

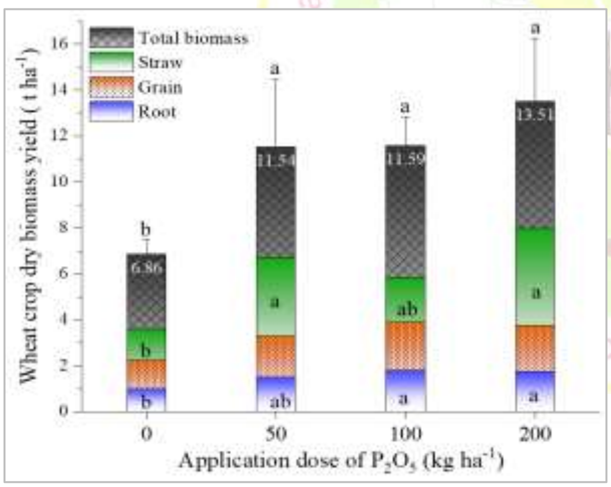

Figure 1. Effect of long-term P application on wheat biomass (total, straw, grain, and root: from top to bottom) at different doses. Bars with the same letter indicate no significant difference at $P < 0.05$.

Response of Nutrient Concentrations in Wheat Grains to P Application Doses

Grain K, Zn, C, and N concentrations were determined to examine the influence of frequent P application doses on grain quality with respect to nutrient accumulation. The results are indicated in Figure 2, and it was found that the long-term application of the P dose did not have a significant impact on the concentrations of grain nutrients. However, there was a decreasing trend in grain Zn level as the P dose increased from P50 to P200 (Figure 2 A).

Relative to the control and P200, grain Zn concentration at P50 was higher by 15.58% and 22.12%, respectively. In general, there is a negative P–Zn interaction with increasing P addition to soil (Sánchez-Rodríguez, Del Campillo and Torrent, 2017). High P levels in the soil can disrupt the plant's ability to efficiently utilize and transport Zn into the sink, resulting in decreased the Zn level in the grains (Ortas and Islam, 2018; Yang, Tian, Lu, Cao and Chen, 2011). A meta-analysis study also showed that P application reduced wheat grain Zn concentration by 16.6% (Zhang *et al*., 2021).

The grain K, C, and N concentrations did not show a consistent trend across the P doses. The highest grain K concentration (0.412%) was observed at P50, and the lowest K (0.386%) was at P0 (Figure 2 A). The results showed that higher P application rates led to marginally higher grain K concentrations despite the lack of statistically significant differences. Grain total C and N followed the same trend, and the highest values for N (2.29%) and C (40.95%) were obtained in P100 (Figure 2 B). For the same experiment, the highest grain C and N in P200 were reported (Akpinar and Ortas, 2023; Işik, Akşahin and Ortaş, 2021). However, the current study showed that P100 produced higher grain C, and N. This indicates that the response of grain nutrient contents to P doses may change over time. Moreover, the higher grain yield obtained at P100 may result in reduced N and C concentrations in the grains due to the dilution effects.

Dynamics of Soil Organic C, Total N, and Mycorrhizal Spores with Varying P Doses

The P application doses had a significant effect on the soil organic carbon (SOC) at 0-15 cm soil depth but were insignificant at 15-30 cm depth (Table 1). All applied P doses were significantly higher than the control (P0) with respect to the SOC at 0-15 cm but insignificant among each other. At P100, the higher SOC (1.49%) was found in the topsoil depth, however, 1.64% SOC was measured at 15-30 cm depth. The higher P level enhances plant biomass productions, including roots, and this might contribute to higher SOC factions. This finding is in agreement with the results of studies that recently reported in the same field conditions that long-term P application had a positive impact on SOC under a wheat cropping system (Akpinar and Ortas, 2023; Ortas and Bykova, 2020; Ortas and Lal, 2012).

The soil TN was significantly affected by P dose application at 0-15 cm depth, while it was not significant at 15-30 cm depth (Table 1). There was no consistent pattern observed in the TN concentration with different P doses. The highest soil TN (0.118%) was obtained at P100 in the top 0-15 cm, and the lowest TN (0.102%) was recorded at P50 in the subsoil. Generally, soil TN was higher in the top 0-15 cm. The soil C:N ratio was also significantly affected by P

fertilizer at both depths and increased as the P dose increased. A higher C:N ratio was determined at P200 (Table 1). This could be the contribution of higher crop residues and biomass produced at higher P doses. It was generally expected that the particulate fraction of SOC wound increased with organic sources from crop residues with a higher C: N ratio, mainly in the wheat cropping system. A similar trend from the same experiment in 2013/14 was found by Akpinar and Ortas (2023).

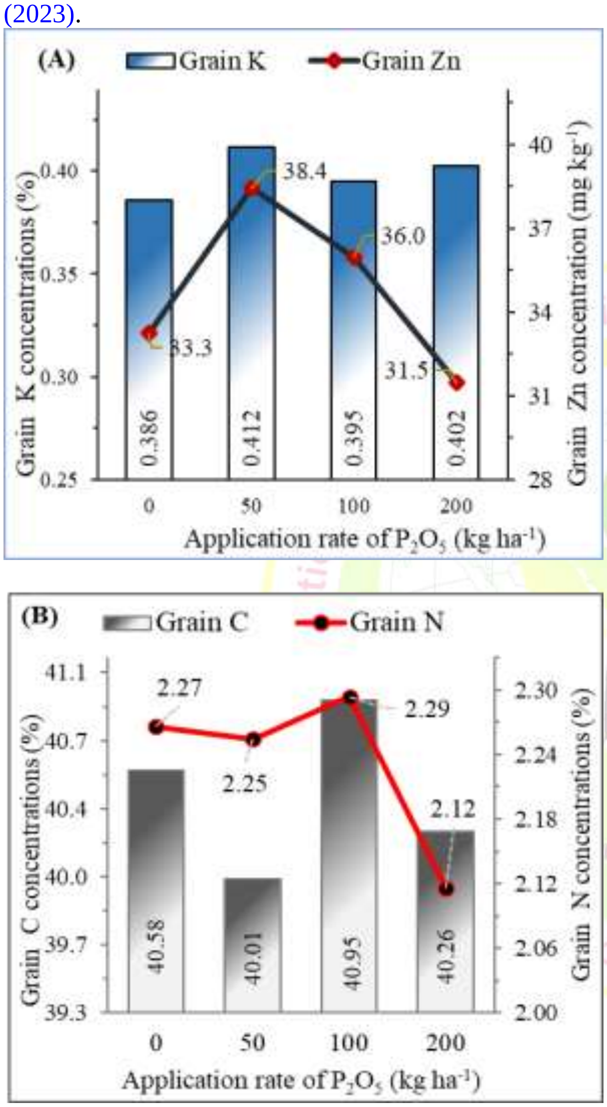

Figure 2. Effect of P application dose on concentrations of K and Zn (A), and total carbon and nitrogen (B) in wheat grain.

Mycorrhizal fungi have a significant impact on mineral nutrient uptake and plant growth. In this study, the wheat crop was not externally inoculated with this fungus. However, to ascertain the effects of P doses on indigenous mycorrhizal spores, the relationship between the applied P dose and the number of native mycorrhizal spores was determined. The study showed that there was no significant effect on spore counts. On average, more mycorrhizal spores (43 spores 10 g soil^{-1}) were recorded in the control plot. A decreasing trend in spore numbers was observed as the P dose increased. The number of spores was generally higher in the surface soil depth than in the 15-30 cm depth. The mycorrhizal dependency of plants and the number of mycorrhizal spores in the soil are reported to decrease when the soil or applied P level is higher (Ortas, 2012; Ortas and Islam, 2018; Treseder, 2004). The decrease in spore count might be attributed to the ineffective symbiotic association of the host plant and the fungus with a higher P dosage.

Table 1. Effect of long-term P application on selected soil properties

P_2O_5 dose (kg ha^{-1})	Soil depth (cm)	Soil OC (%)	Soil TN (%)	C: N ratio	Mycorrhizal spore numbers per 10 g soil
0	0-15	1.05 ^{b}	0.108 ^{b}	9.75 ^{b}	43.00
50		1.38 ^{a}	0.115 ^{ab}	12.01 ^{a}	28.00
100		1.49 ^{a}	0.118 ^{a}	12.61 ^{a}	18.67
200		1.47 ^{a}	0.115 ^{ab}	12.81 ^{a}	26.67
LSD (P<0.05)		0.19	0.0105	1.423	25.76 (NS)
0	15-30	1.27	0.107	11.84 ^{b}	18.67
50		1.30	0.102	12.83 ^{ab}	17.33
100		1.64	0.105	15.58 ^{a}	13.33
200		1.61	0.104	15.46 ^{a}	19.00
LSD (P<0.05)		0.449 (NS)	0.016 (NS)	2.969	14.01 (NS)

*NS=Not significant

CONCLUSIONS

In a 23-year-old field experiment, the objectives of this study were to explore the long-term effects of different doses of P (0, 50, 100, and 200 kg P2O5 ha^{-1}) fertilizer on the total dry biomass yield of wheat, the levels of nutrients in the grain, and certain soil properties. The results showed that P application doses had a significant impact on wheat crop biomass. The total dry biomass yield of wheat increased linearly with the P application dose. However, the grain yield and root biomass started to decline at P200. The study also revealed that grain K, Zn, C, and N concentrations were unaffected considerably by the long-term P dose application. While larger grain C and N concentrations were found in the P100 treatment plots, it was noticed that grain, Zn, P, and K levels were relatively higher in the P50 treatment. However, the concentration of Zn in the grain showed a decreasing trend as the dose of P fertilizer increased. This indicates that, as supported by many studies, a higher P dose has an antagonistic effect on the concentration of Zn in the grain. The P doses had a varying effect on soil properties. The soil OC and TN at 0-15 cm depth, increased significantly with P application doses relative to the control. The higher biomass production might contribute to the increased SOC. However, at the 15–30 cm soil depth, the impact of P dosages on SOC was insignificant. There was no discernible difference between P50, P100, and P200 in terms of the soil total N at the 0-15 cm depth. The application of P dosage had no appreciable impact on the soil TN at a depth of 15 to 30 cm depth. Despite the lack of a noticeable difference between the applied P

doses, adding P fertilizer increased the soil C to N ratio. The number of mycorrhizal spores did not show significant changes with increasing P doses. The control plot showed higher spore counts; however, as the dosage of P increased, the spore numbers tended to decline. In conclusion, our study suggests that a long-term application of 100 kg P_2O_5 ha^{-1} is recommended based on wheat productivity, grain nutrient concentration, and soil OC storage. However, further investigation is needed to determine the efficiency of P, the soil nutrient balance, and the environmental impacts of the applied P doses.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

Bird diversity of in and around Melamadai Lake Madurai city, Tamil Nadu state, India; A preliminary study

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ABSTRACT
Fresh water Lakes are suitable habitat for birds along with food and water. In the present study an attempt has been made to assess the diversity of avian fauna in Melamadai Lake in Madurai district, Tamilnadu state. The duration of study period in January 2021 to December 2021. Eighty-four species of birds were observed, belonging to 41 families, 18 order in Melamadai lake. In this study recorded in Least concern (LC) 79 species and Near Threatened (NT)Five species. The five Near Threatened species - Oriental Darter (*Anhinga melanogaster*), Pied Cuckoo-dove(*Reinwardtoena browni*), Spot-billed Pelican (*Pelecanus philippensis*), Black-headed Ibis (*Threskiornis melanocephalus) and* Painted Stork-*(Mycteria leucocephala)*- are protected under Schedule IV of the Indian Wildlife Protection Act, 1972. The diversity of avifauna is taken for identifying the importance of biodiversity for Madurai which is among the top ten tourism sites of world. The role of urban areas in functions such as provision of ecosystem services will largely be determined by patterns of biodiversity within that area.
Keywords: Birds, species, diversity, Lake, Status, wetland, Madurai.

INTRODUCTION

Aquatic ecosystems are important one which provide livelihoods for the millions of people who live around them. Man depends ponds for most of his needs like fishing, agriculture, irrigation, and other domestic purposes. Ponds are playing a very good role in rain harvesting, storage of water and regulation of ground water level. So in order to maintain the ground water level we must conserve ponds and pond habitat. Birds are found throughout the world, at approximately all altitudes and nearly every climate. They are a natural way to control pests in gardens, on farms and in aquatic ecosystems (HV Wanjari ;2016).

India has around 67,429 wetlands, covering an area of about 4.1 million hectares. Out of these, 2,175 are natural and 65,254 are manmade. Wetlands in India (excluding rivers), account for 18.4% of the country's geographic area, of which 70% is under paddy cultivation (MoEF 1990; Parekh & Gadhvi 2013). Many species of birds respond to small changes in habitat structure and composition, therefore they serve as good indicators of changes in the environment. The presence of aquatic birds anywhere speaks volumes of the environment as to whether all is well or there is something amiss. It also shows the biological importance or going technical, the biodiversity significance of an area (HV Wanjari ;2016). Wetlands in India provide a unique habitat to many aquatic Flora and fauna as well as numerous birds including migratory species. Out of 310 species of wetland birds found in India (Kumar et al. 2005; Kumar & Gupta 2009, 2013) almost half are migratory which visit India from cold areas of different parts of China, Russia, central Asia, and from across the entire range of the Himalaya. Freshwater lakes one of the important types of wetlands, play a vital role in the economics of their respective regions, especially with reference to agriculture, fishing, livestock maintenance and drinking water facilities of the adjacent areas. The geographic location of a wetland may determine how and when birds will use it or use adjacent habitat (Manikannan, 2011).

Birds are essential animal group of an ecosystem which play a functional role in the ecosystem and are rightly called as bioindicators. There are more than 10000 bird species in the world, out of these 1313 species recorded from Indian subcontinent (Grimmett *et al*. 2011).

MATERIALS AND METHODS

Study area:

Figure 1. shows the Melamadai lake is located at 9°56'N latitude, 78°98'E longitudes. The lake belongs to Melamadai village in Madurai North taluk and Madurai East block. Melamadai lake is surrounded by Urbanization. It has abundant species richness due to suitable surrounding environment. The water body provides good habitat for many fishes, amphibian, odonates, etc., whereas the surrounding forest is a good habitat for bird, reptiles and other animals. The

Melamadai Lake was irrigation, domestic water supply and to provide water for livestock as well as controlling floods and reduction of problem of water shortage for the people living in Nearby and surrounding villages.

Survey of birds:

Data were collected using three methods: transect walk, point transects and direct observations. The most of surveys on the wetland's avifauna were conducted between January 2021 to December 2022 using a transect line approach (Bibby *et al.*, 1992) to extensively survey throughout the wetland area so as to assess the avifauna species and abundance. The birds' observations were carried out twice daily; morning between 6.30 to 10 AM and evening 3.30 to 6.30 PM, between 1600 and 1800 h by walking slowly along transects. Birds were counted as bird seen and heard and birds in flight were also recorded.

Table 1. Avifauna recorded from Melamadai Lake, Madurai district, Tamil Nadu.

S.No	Order	Family	Common name	Scientific name	IUCN status
1	Apodiformes	Apodidae	Asian Palm-Swift	Cypsiurus balasiensis	LC
2	Accipitriformes	Ardeidae	Cattle Egret	Bubulcus ibis	LC
3	Accipitriformes	Accipitridae	Shikra	ccipiter badius	LC
4	Anseriformes	Anatidae	Garganey	Spatula querquedula	LC
5	Accipitriformes	Accipitridae	Brahminy Kite	Haliastur indus	LC
6	Anseriformes	Anatidae	Indian Spot-billed Duck	Anas poecilorhyncha	LC
7	Anseriformes	Anatidae	Fulvous Whistling-Duck	Dendrocygna bicolor	LC
8	Anseriformes	Anatidae	Lesser Whistling-Duck	Dendrocygna javanica	LC
9	Apodiformes	Apodidae	Little Swift	Apus affinis	LC
10	Anseriformes	Anatidae	Northern Shoveler	Spatula clypeata	LC
11	Columbiformes	Columbidae	Rock Pigeon	Columba livia	LC
12	Columbiformes	Columbidae	Eurasian Collared-Dove	Streptopelia decaocto	LC
13	Cuculiformes	Cuculidae	Asian Koel	Eudynamys scolopaceus	LC
14	Coraciiformes	Alcedinidae	White-throated Kingfisher	Halcyon smyrnensis	LC
15	Columbiformes	Columbidae	Western Spotted Dove	Spilopelia suratensis	LC
16	Coraciiformes	Meropidae	Green Bee-eater	Merops viridissimus	LC
17	Coraciiformes	Meropidae	Blue-tailed Bee-eater	Merops philippinus	LC
18	Cuculiformes	Cuculidae	Greater Coucal	entropus sinensis	LC
19	Columbiformes	Columbidae	Pied Cuckoo-dove	Reinwardtoena browni	NT
20	Charadriiformes	Recurvirostridae	Black-winged Stilt	Himantopus himantopus	LC
21	Charadriiformes	Scolopacidae	Ruff	Calidris pugnax	LC
22	Charadriiformes	Laridae	Whiskered Tern	Chlidonias hybrida	LC
23	Coraciiformes	Coraciidae	Indian Roller	Coracias benghalensis	LC
24	Charadriiformes	Charadriidae	Red-wattled Lapwing	Vanellus indicus	LC
25	Charadriiformes	Scolopacidae	Green Sandpiper	Tringa ochropus	LC
26	Charadriiformes	Scolopacidae	Wood Sandpiper	Tringa glareola	LC
27	Charadriiformes	Scolopacidae	Common Sandpiper	Actitis hypoleucos	LC
28	Charadriiformes	Laridae	Common Tern	Sterna hirundo	LC
29	Coraciiformes	Alcedinidae	Common Kingfisher	Alcedo atthis	LC
30	Coraciiformes	Alcedinidae	Pied Kingfisher	Ceryle rudis	LC
31	Columbiformes	Columbidae	Laughing Dove	Spilopelia senegalensis	LC
32	Cuculiformes	Cuculidae	Blue-faced Malkoha	Phaenicophaeus viridirostris	LC
33	Charadriiformes	Scolopacidae	Common Snipe	Gallinago gallinago	LC
34	Ciconiiformes	Ciconiidae	Painted Stork	Mycteria leucocephala	NT
35	Charadriiformes	Scolopacidae	Marsh Sandpiper	Marsh Sandpiper	LC
36	Galliformes	Phasianidae	Indian Peafowl	Pavo cristatus	LC
37	Gruiformes	Rallidae	Eurasian Coot	Fulica atra	LC
38	Gruiformes	Rallidae	White-breasted Waterhen	Amaurornis phoenicurus	LC
39	Gruiformes	Rallidae	Watercock	Gallicrex cinerea	LC
40	Galliformes	Phasianidae	Gray Francolin	Francolinus pondicerianus	LC
41	Pelecaniformes	Ardeidae	Gray Heron	Ardea cinerea	LC
42	Pelecaniformes	Ardeidae	Purple Heron	Ardea purpurea	LC
43	Pelecaniformes	Ardeidae	Indian Pond-Heron	Ardeola grayii	LC
44	Pelecaniformes	Ardeidae	Black-crowned Night-Heron	Nycticorax nycticorax	LC
45	Pelecaniformes	Threskiornithidae	Glossy Ibis	Plegadis falcinellus	LC
46	Psittaciformes	Psittaculidae	Rose-ringed Parakeet	Alexandrinus krameri	LC
47	Passeriformes	Dicuridae	Black Drongo	Dicrurus macrocercus	LC
48	Passeriformes	Corvidae	Rufous Treepie	Dendrocitta vagabunda	LC
49	Passeriformes	Corvidae	House Crow	Corvus splendens	LC

50	Passeriformes	Cisticolidae	Common Tailorbird	Orthotomus sutorius	LC
51	Passeriformes	Pycnonotidae	Red-vented Bulbul	Pycnonotus cafer	LC
52	Passeriformes	Leiothrichidae	Yellow-billed Babbler	Argya affinis	LC
53	Passeriformes	Sturnidae	Common Myna	cridotheres tristis	LC
54	Passeriformes	Nectariniidae	Purple Sunbird	Cinnyris asiaticus	LC
55	Pelecaniformes	Ardeidae	Little Egret	Egretta garzetta	LC
56	Passeriformes	Dicruridae	Ashy Drongo	Dicrurus leucophaeus	LC
57	Passeriformes	Hirundinidae	Barn Swallow	Hirundo rustica	LC
58	Passeriformes	Nectariniidae	Purple-rumped Sunbird	Leptocoma zeylonica	LC
59	Passeriformes	Motacillidae	Yellow Wagtail	Motacilla flava	LC
60	Passeriformes	Laniidae	Brown Shrike	Lanius cristatus	LC
61	Passeriformes	Cisticolidae	Ashy Prinia	Prinia socialis	LC
62	Passeriformes	Cisticolidae	Plain Prinia	Prinia inornat	LC
63	Passeriformes	Acrocephalidae	Blyth's Reed Warbler	Acrocephalus dumetorum	LC
64	Podicipediformes	Podicipedidae	Little Grebe	achybaptus ruficollis	LC
65	Pelecaniformes	Pelecanidae	Spot-billed Pelican	Pelecanus philippensis	NT
66	Pelecaniformes	Ardeidae	Yellow Bittern	Ixobrychus sinensis	LC
67	Passeriformes	Acrocephalidae	Clamorous Reed Warbler	Acrocephalus stentoreus	LC
68	Passeriformes	Motacillidae	Western Yellow Wagtail	Motacilla flava	LC
69	Passeriformes	Motacillidae	White-browed Wagtail	Motacilla maderaspatensis	LC
70	Pelecaniformes	Ardeidae	Black Bittern	Ixobrychus flavicollis	LC
71	Passeriformes	Corvidae	Large-billed Crow	Corvus macrorhynchos	LC
72	Pelecaniformes	Threskiornithidae	Black-headed Ibis	Threskiornis melanocephalus	NT
73	Passeriformes	Estrildidae	Indian Silverbill	Euodice malabarica	LC
74	Passeriformes	Alaudidae	Jerdon's Bushlark	Mirafra affinis	LC
75	Passeriformes	Acrocephalidae	Booted Warbler	Iduna caligata	LC
76	Passeriformes	Sturnidae	Rosy Starling	Pastor roseus	LC
77	Passeriformes	Dicaeidae	Pale-billed Flowerpecker	Dicaeum erythrorhynchos	LC
78	Passeriformes	Motacillidae	Paddyfield Pipit	Dicaeum erythrorhynchos	LC
79	Passeriformes	Passeridae	House Sparrow	Passer domesticus	LC
80	Passeriformes	Oriolidae	Indian Golden Oriole	Oriolus kundoo	LC
81	Suliformes	Anhingidae	Oriental Darter	Anhinga melanogaster	NT
82	Suliformes	Phalacrocoracidae	Indian Cormorant	Phalacrocorax fuscicollis	LC
83	Suliformes	Phalacrocoracidae	Little Cormorant	Microcarbo niger	LC
84	Strigiformes	Strigidae	Spotted Owlet	Athene brama	LC

Table 2. Showing in IUCN status of birds in Melamadai Lake

S.No	IUCN status	Number of birds
1	Least Concern (LC)	79
2	Near threatened (NT)	5
	Total	84

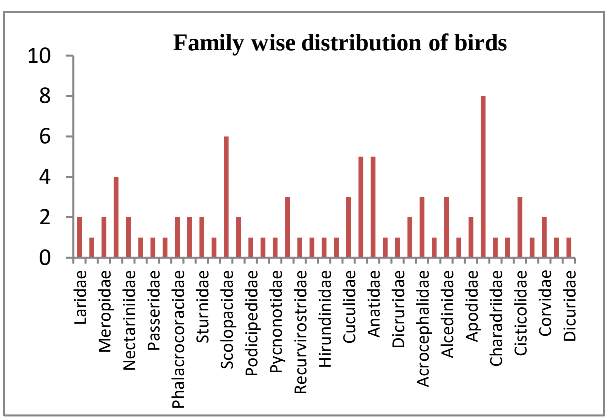

Figure 1. Family level distribution of birds in Melamadai lake.

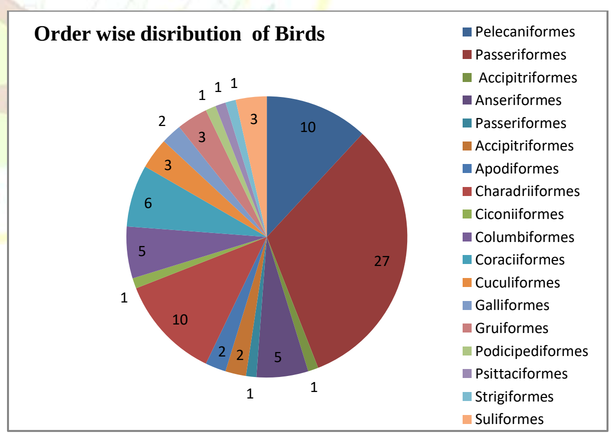

Figure 2. Order wise distribution of birds in Melamadai lake, in Madurai district, Tamil Nadu

RESULTS AND DISCUSSION

The present study revealed the occurrence of a total of 84 bird species belonging to 41 families and 18 orders from the study area. Details such as common names, scientific names, and Occurrence IUCN conservation status of the wetland birds are presented in Table 1. The order dominated list Ardeidae(8 species), Scolopacidae (6 species), Columbidae (5 species), Anatidae

(5 species), Motacillidae (4 species), Rallidae (3 species), Acrocephalidae (3 species), Cuculidae (3 species), Cisticolidae(3 species), Alcedinidae(3 species), Meropidae (2 Species), Laridae(2 species), Nectariniidae (2 species), Apodidae(2 species), Phalacrocoracidae (2 species), Phasianidae (2 species), Threskiornithidae(2species), Sturnidae (2 species), Accipitridae (2 species), Apodidae (2 species)and Leiothrichidae. Oriolidae, Passeridae, Pelecanidae, Strigidae, Podicipedidae, Psittaculidae, Pycnonotidae, Recurvirostridae, Laniidae, Hirundinidae, Estrildidae, Corvidae, Dicruridae, Alaudidae, Anhingidae, Charadriidae, Ciconiidae, Coraciidae, Corvidae, Dicaeidae, Dicuridae Each order are recorded in one species(Figure 2) .

The family are represented in dominated list are Passeriformes (27species), Pelecaniformes (10 species), Charadriiformes (10 species), Columbiformes (5Species), Coraciiformes (6species), Anseriformes (5 species), Suliformes (3species), Cuculiformes(3 species), Galliformes (2species), Gruiformes (3species), Accipitriformes (2 species), Apodiformes (2species) and Podicipediformes, Accipitriformes, Passeriformes, Ciconiiformes, Psittaciformes, Strigiformes each familes are recorded in one species (Figure 2). (M.N Harisha *et*,. *al*.2018)The family Ardeidae dominated by the representation of 10 species (19%) followed by Scolopacidae with seven species (13%), Rallidae with six species (12%), Anaidae with ive species (10%), Motacillidae with four species (8%), Alcedinidae, Charadriidae, Ciconiidae with three species each, (6% each), Laridae, Threskiornithidae, Phalacrocoracidae with two species each (4% each), Podicipididae, Anhingidae, Rostratulidae, Recurvirostridae with one species each (2%) each of the total family wise frequency of occurrence of water birds community of the study area.

As per IUCN Red List (IUCN 2014.3) threatened categories, 46 species recorded from the study areas fall under the Least Concern (LC) category, which account for 90% and five species (10%) were categorized as Near Threatened (NT), (M.N. Harisha *et al* 2018).In this study recorded in Least concern(LC) 79 species and Near Threatened (NT)Five species (Table 2.The five Near Threatened species - Oriental Darter(*Anhinga melanogaster)*, Pied Cuckoo-dove(*Reinwardtoena browni)*, Spot-billed Pelican (*Pelecanus philippensis)*, Black-headed Ibis (*Threskiornis melanocephalus) and* Painted Stork-*(Mycteria leucocephala)*- are protected under Schedule IV of the Indian Wildlife Protecion Act, 1972 (Arora 2003).

The birds were found to utilize different wetland habitats extensively for nesting, foraging and roosting on the vegetation. Due to the availability of varied sources of feed as well as foraging, the rich diversity of the birds was documented during the present study. The wetlands provides heterogeneous feeding habits to avifauna (Saika, P. K;2000).Wetland habitat by supporting different food sources like planktons, fishes and invertebrates, further adding to the diversity of the wetlands (Jules, E. S., 1997). From in this study onwards a considerable number of water birds dwell in the pond. Highest density of the birds was recorded during winter months. The basic requirement of the migratory birds at their wintering sites are adequate food supply and for their safety (Bharatha Lakshmi, B. 2006).

It is indicated that Melamadai Lake was more potential than the wetland for birds' diversity. It is realized that the birds turn out to be excellent indicator of overall biodiversity such as fishes and zooplankton and benthic fauna etc as the inhabit a broad range of habitats and elevations. Some seasonal changes in water birds' number is directly or indirectly connected to the availability of food and water physico-chemical characters.

The present study emphasizes the need for the conservation of wetlands and their biodiversity and specially the wetland migratory birds. The urgency is verified due to the international significance of these globally Near Threatened birds of importance. Hence, small urban wetlands should be also prioritized for conservation and their values should be recognized for the protection of avifauna.

So, it can be inferred from present investigation that aquatic ecosystem of lake is degrading as presence of pollution indicators forms and slowly this beautiful lake will perish or will may lost from human use.

CONCLUSIONS

The present study revealed that, though the lake is highly disturbed it still provides some potential habitats for a few migratory as well as all residents, including some threatened species which have a declining population trend by providing food and space to breed. It is the need of the hour to monitor systematically in the rapidly changing environment with a focused study on the avifauna of the region. This can be achieved only through strengthening public participation in the study of status, distribution and conservation of birds of Melamadai Lake, Madurai District, and Tamil Nadu.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

Assessment of the Role of Leasehold Forest in Livelihood Improvement in Gorkha District, Nepal

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ABSTRACT
The leasehold forestry aims to free the poor from a complicated cycle of poverty by institutionalizing and manipulating the local resources. This study is based on the structured and semi-structured questionnaire and an examination of both published and unpublished records. The study was carried out in 283 Leasehold Forest User Groups (LHFUGs) of the Gorkha district representing 8 different clusters. This study makes a clear effort to identify livelihood improvement in the Gorkha district through leasehold forest by taking into consideration livelihood assets (natural, physical, human, financial, and social). The condition of livelihood capitals in the study area was examined using a judgmental scoring technique that looked at the changes that occurred in five different capitals. Three indicators have been used for each of the assets and scores; +1, -1, and 0 were given to represent improved, degraded, and remained unchanged respectively. A spider web diagram was used to express the change. The results depicted that Chepang, Gurung, and Magar are the predominant indigenous peoples who benefited from the LHF. The result showed the constructive impact of the leasehold forestry program on each asset. The social, physical, human, natural and financial capital received an average total score of 0.778, 0.951, 0.748, 0.589, and 0.722 respectively. The most notable accomplishments were construction and access to the physical capitals including the effectiveness of constructions and advancement of knowledge about community development. Better-managed natural resources can help achieve both conservation and livelihood options.
Keywords: Livelihood, Leasehold forestry, Gorkha, Forest, Forest User Group.

INTRODUCTION

Forest is an essential part of the subsistence agriculture that the majority of rural Nepalese people use (Gautam et al., 2004). It fulfills the need for fodder and leaf litter for livestock, construction materials, raw materials for forest-based industries, sources of energy, etc. It helps to maintain the quality of the watershed and hence is the source of drinking water for households and irrigation systems. Other than the consumptive value of forest it also provides a vast range of social, cultural, and environmental benefits (Gautam et al., 2004).

Forest rights and ownership of Nepal were transferred to the government in 1957 with the nationalizations act after which the government became unable to enforce forest management regulations and hence excessive deforestation and degradation rise as a major problem in forest resource conservations (Kanel & Dahal, 2008). To tackle the problem and resolve the issues of forest degradation and deforestation, a concept of participatory forest management was initiated as a novel concept of forest management in the 1970s. There are six distinct modes of participatory forest management. Over the past three decades, Nepal has implemented community, leasehold, collaborative, religious, forest protection area, and buffer zone forestry as a strategy for reducing poverty and conserving natural resources (Gautam et al., 2008). Although community forestry played a significant role in forest resources conservation and rehabilitation of the degraded area, equity in benefit sharing always remained problematic and poor households typically receive less benefit than the relatively better off (Bhattarai et al., 2007). So, to eliminate the prevailed discrimination and with the aim of uplifting the livelihood of poor and back warded people, the Government of Nepal promoted poor people focused Leasehold forestry program in 1993 through the Hills Leasehold Forestry and Feed Development Project (HLFFDP) and since 2004 through the Leasehold Forestry and Livestock Development Program (LFLP).

The process of gaining access to a variety of livelihood assets or capitals, such as financial, human, social, physical, and natural assets, through a variety of livelihood strategies with the goal of achieving particular livelihood outcomes is fundamental to the concept of livelihoods (Ellis, 2000). Human capital refers to the

skill, knowledge, health status and ability of a person whereas social capital refers to the access of the person to social resources, inclusions, and public relations. Natural asset signifies the access of the person to natural resources such as water resources, forest resources, land, etc. Financial assets of livelihood refer to access to financial services and income-generating activities whereas physical assets refer to the basic physical infrastructure that the person needs to make his/her livelihood. Access to these assets determines people's ability to own, regulate, claim, or use resources that together evaluate an individual's or a household's standard of living (Ellis, 2000).

Forest Rules 1995 made provisions to handover the degraded land to the group of people that are under the line of poverty (PCI below NRs. 3,3035 per year and land holding less than 10 rapani). Thus, poor households get access to land for 10 years (Forest Regulation, 2079) which helps them to improve their livelihood. People can enhance their income through IGAs such as animal husbandry, apiculture, Sericulture, NTFPs cultivations, etc. It also promotes the participation of women and makes a remarkable shift towards sharing decision-making among men and women (Yadav and Dhakal 2000; Ohler, 2003). As a result, the LF program has been successful in improving the various capitals of the poor's livelihoods by increasing livestock production and restoring degraded land. (Ohler 2003).

Alongside this success, the scientific study related to the role of LF at the ground level in alleviating poverty is very less. Most of the studies are focused on the role of community forestry in livelihood improvement. Due to this, the learning and experience from leasehold forestry practice have not been well understood and have got relatively less priority in the policy. So, this paper seeks to analyze the extent to which the leasehold program has been successful in achieving the goal of enhancing sustainable livelihood capitals of the poor community of Gorkha, Nepal.

MATERIALS AND METHODS

Study area:

The study was conducted in 283 Leasehold Forest User Groups (LHFUGs) of the Gorkha district representing 8 different clusters as presented in Table 1. Gorkha, the fourth largest district of Nepal lies at the latitude of 28° 28' 35.0220" North and the longitude of 84° 41' 23.1036" East with an area of 3,610.70 Square kilometers. The elevation ranges from 330 m (Trishuli river bank) to 8,156 m (Mt. Manaslu) above sea level. The climatic zone of the district varies from the lower tropical zone in the South to the Trans-Himalayan zone in the North. The average yearly precipitation is 254.87 mm and the annual highest and lowest temperature varies from 19.35ºC to 10.09ºC. According to the Division Forest office, Gorkha, the total forest cover is 1, 32,120 hc of which 983.63 ha is covered by the Leasehold Forest.

Table 1: Studied Clusters of Leasehold Forest in Gorkha, Nepal

S. No	Name of Cluster	Address
1	Manakamana Cluster	Sahid Lakhan RM-3 and Gorkha Municipality-1
2	Masel Baguwa Cluster	Bhimsen RM-1 and 5
3	Simjung Muchchowk Cluster	Ajirkot RM-4,5 and Palungtar-1
4	Chyangli Gaikhur Cluster	Palungtar Municipality-4,6,7,8
5	Taklung Cluster	Sahid Lakhan RM-2,3,4
6	Tanglichowk Makaisingh Cluster	Gandaki RM-1,2
7	Bhumlichowk Cluster	Gandaki RM-6
8	Darbung Cluster	Gandaki RM-5,7,8

Field Survey:

Field surveys were undertaken in February 15 to May 12, 2022. Key informant surveys, focus groups, checklists, and field observations were the primary survey tools used for data collection. On the basis of an open-ended questionnaire, 478 houses were surveyed out of a total of 2359 households. Yamane's Taro Yamane Formula (1973) was used to determine the sample size.

Sample size, $n = z^2*p\,(1-p)/e^2/1+ (z^2*p\,(1-p)/e^2N)$

Where, n = Sample size

Z = Value of variance at 95 % (1.96)

P = 0.5

e = Margin of error at 4% (0.04)

N = Total number of Households

The secondary data was gathered using the records of the relevant line agencies, including Division Forest Office annual reports, LHFUG records, and published and unpublished literature.

The gathered data were examined using a variety of des criptive statistical methods.

Fig1: Study Area Map (Gorkha,Nepal)

Assessment of Livelihoods Using a Sustainable Livelihood Framework

The contribution of leasehold forestry to the livelihoods of forest user communities was evaluated using the sustainable livelihood paradigm, which was developed by the Institute of Development Studies (IDS) and later modified by DFID in 1999. Table 2 shows several indicators that have been used to measure livelihood capital. The evaluation was conducted on judgmental scoring systems. Three scores were given to each of the five capitals' indicators to determine whether their conditions improved, declined, or remained unchanged: +1, -1, and 0 in turns. (Table 2)

Table 2: Indicators used for the assessment of livelihood capital

Livelihood Capitals	Indicators Used
Natural Capital	a) Ease in accessing the forest product collection after the handover of LHF b) Incidences of Forest fire, Grazing, Drying up of water resources, Encroachment c) Improvement in greenery and landscape beauty
Physical Capital	a) Construction and access to physical capital b) Effectiveness of construction c) Enhancement of knowledge regarding community development activities
Social Capital	a) Relation among user groups after the handover of LHF b) Decision-making capacity about resources management and use d) The major role played in decision making
Financial Capital	a) Increment in employment opportunities b) Income from forest products collection c) Provisions of loans for IGAs
Human Capital	a) Condition of awareness regarding responsibilities among user groups b) State of skills and knowledge on forest management c) Changes in leadership capacity

Each capital's changes were examined using three different indicators. After that, the average scores of each indicator of each capital were added and divided by three as three indicators were used for each capital. It was depicted as a web in a diagram with the form of the pentagon indicating the variation in access to each capital (Chapagain, 2007). Accessibility to capitals is based on the idea that the outer edge of the Pentagon has the most access while the center of the Pentagon has no access to any of the capitals. (Poudel, 2004).

RESULTS AND DISCUSSION

Communities involved in LHFUG

Among 2359 households involved in the Leasehold Forest, the households of Indigenous people, Dalit communities, Brahmin and Chettri, and other communities were 1645, 388, 296, and 30 respectively (fig. 2). Chepang, Gurung, and Magar are the predominant Indigenous peoples who benefited from LHF.

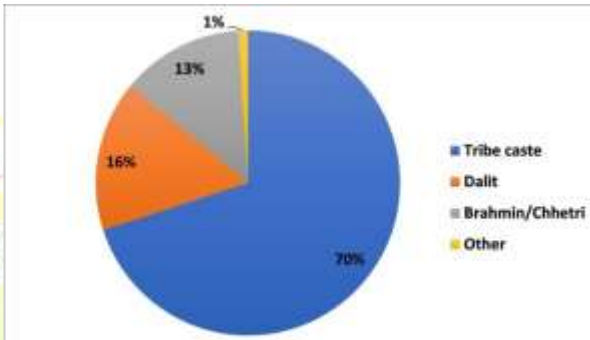


Fig. 2: Households involved in LHF from different communities

Status of Leasehold Forest Management

The forest was handed over to the LHFUGs with members of 5 to 15 households. Each household received an equal share of the LHF to manage and execute a wide range of activities in its own way. LHFUGs were given assistance in developing ten-year forest management plans, as well as technical guidance and training from the Division Forest Offices, Gorkha to aid them in restoring the forest on their plots. The groups were also given basic inputs such as tools, seeds, seedlings of multi-purpose tree species (MPTs), and goats as a livelihood upliftment program, as well as microcredit chances to start income-generating businesses. Some of the major forest management and income-generating activities (IGAs) in the LHFs are listed below in Table 3:

Status of Livelihood Capitals in LHFUGs of 8 Clusters

The average value of Physical capital ranged between 1 to 0.833, being a maximum 1 of Chyangli-Gaikhur, Masel-Baguwa, and Simjung-Muchchowk clusters followed by 0.98 for the Darbung cluster, 0.949 for Manakamana and Taklung cluster, 0.892 of Tanglichowk-Makaisingh cluster and 0.833, a minimum of Bhumlichowk cluster. The average value of natural capital ranged between 0.858 to -0.395, being a maximum 0.858 of Chyangli cluster followed by 0.854 of Simjung-Muchchowk cluster, 0.838 of Manakamana and Taklung cluster, 0.833 of Tanglichowk-makaisingh cluster, 0.656 of Masel-Baguwa cluster, 0.549 of Darbung cluster and a minimum -0.395 of Bhumlichowk

cluster whereas the average value of human capital ranged between 1 to -0.083, being a maximum 1 of Chyangli-Gaikhur, Masel-Baguwa and Simjung-Muchchowk cluster followed by 0.941 of Darbung cluster, 0.608 of Tanglichowk-Makaisingh cluster, 0.607 of Manakamana and Taklung cluster and a minimum -0.083 of Bhumlichowk cluster. The Bhumlichowk cluster was found much poorer (negative) in the case of natural and human capital than other clusters.

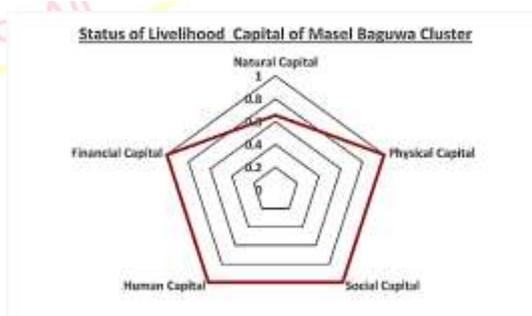
Table 3: Major Forest Management and IGAs in LHFs of Gorkha, Nepal

S.N.	Major Activities	Income Generating Activities
1	Plantation	Trees and various grass species plantation were carried out (Grass: Stylo, Napier, molasses) Trees: Katus, Badahar, Uttis, Chilaune, Sindure and Tanki
2	Livestock and Poultry Farming	Goat, Cattles, Hen
3	Fruits and Vegetable Farming	Fruits: Papaya, Banana, Pineapple, Bayer, Lemon Vegetables: Cauliflower, Cabbage, Cucumber, Tomato, Potato
4	NTFPs Farming	Amriso, Tejpat, Cardamom, Timur
5	Nursery Management	Nursery beds preparation, planting procedures, use of fertilizers, soil management, irrigation, control of seedling density and pest control
6	Training and workshop	Knitting, Handicraft, Farming, Plantation, Accounting, Women Empowerment, Micro-enterprises, etc.
7	Others	REDD programs Implementation, loan provision, fund mobilization, Saving credit program

This was due to frequent soil erosion and forest fire mainly and grazing, encroachment to some extent. The average value of social capital ranged between 1 to 0.083, being a maximum 1 of Chyangli-Gaikhur, Masel-Baguwa, and Simjung-Muchchowk clusters followed by 0.941 of Darbung cluster, 0.821 of Manakamana and Taklung cluster, 0.717 of Tanglichowk-Makaisingh cluster and a minimum 0.809 of Bhumichowk cluster. Similarly, the average value of financial capital ranged between 1 to 0.094, being a maximum 1 of Chyangli-Gaikhur, Masel-Baguwa and Simjung-Muchchowk cluster followed by 0.961 of Darbung cluster, 0.667 of Manakamana and Taklung cluster, 0.65 of Tanglichowk-Makaisingh cluster and a minimum 0.094 of Bhumlichowk cluster. All these results show relatively less contribution of the leasehold forestry program in the Bhumlichowk cluster in improving the status of those livelihood capitals.

Table 4: Livelihood Capital Status in 8 Clusters of LHFUGs in Gorkha, Nepal

Cluster Name	Natural Capital	Physical Capital	Social Capital	Human Capital	Financial Capital
Bhumlichowk	-0.395	0.833	0.083	-0.083	0.094
Tanglichowk Makaisingh	0.833	0.892	0.717	0.608	0.65
Darbung	0.549	0.98	0.941	0.941	0.961
Manakamana	0.838	0.949	0.821	0.607	0.667
Chyangli Gaikhur	0.858	1	1	1	1
Taklung	0.838	0.949	0.821	0.607	0.667
Masel Bagawa	0.656	1	1	1	1
Simjung Muchchowk	0.854	1	1	1	1



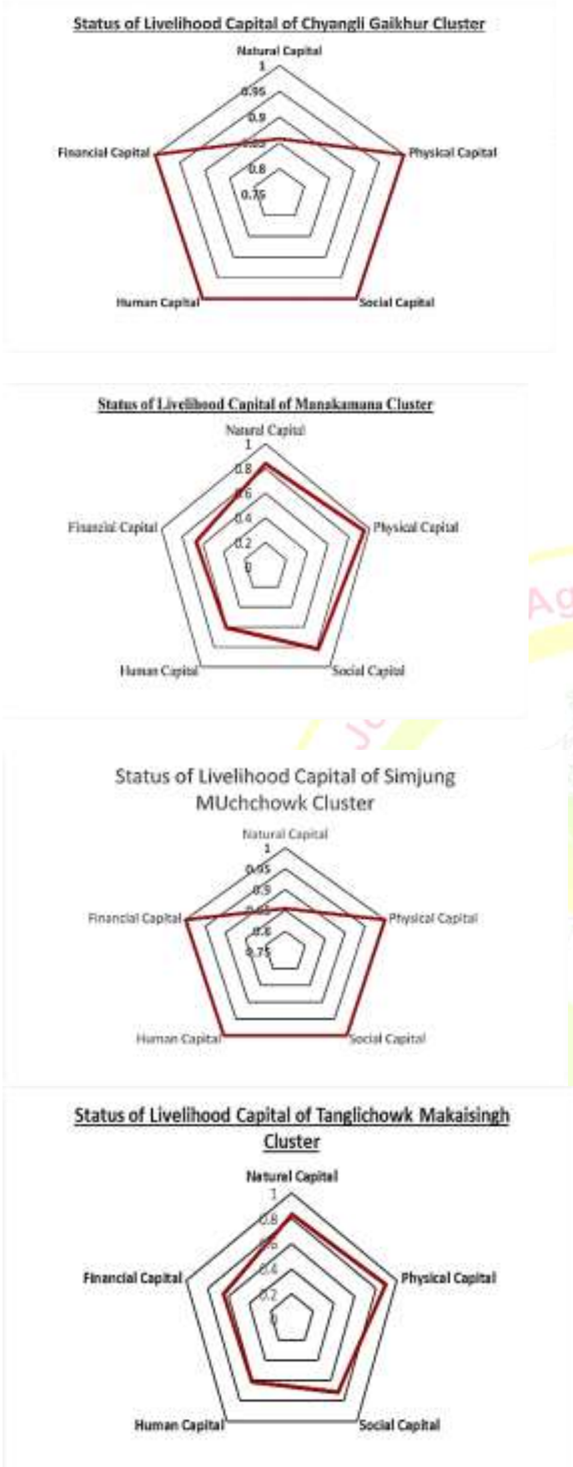


Fig.3. Showing the Individual Status of 8 Different LHFs Cluster in Gorkha, Nepal

Overall Status of Livelihood Capitals of LHFUGs in Gorkha

The indicators used to assess social capital were meeting organization and group discussion, LHFUGs member's participation in the decision-making process about forest resource management, and the relationship between LHFUGs members and community members after the transfer of power of LHF, and the average score for each of these indicators were 0.732, 0.774, and 0.923, respectively and hence the social capital received an average total score of 0.778. It evidences the constructive role of the leasehold forestry program in enhancing social assets. It is also supported by the findings of SEEPORT, 2014 which states that the Gorkha has a larger percentage of female decision-making households (37.5%), also the majority of the women that raise their voices are dalits and Janajaties (SEEPORT, 2014).

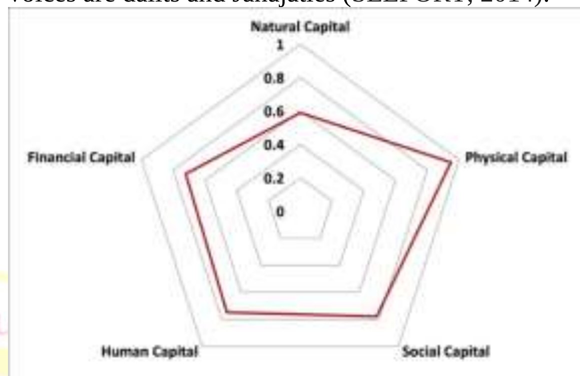


Fig. 4: Status of Livelihood Capital of Leasehold Forest

Our study shows the positive impacts of the leasehold program on physical capital in line with the findings by SEEPORT, 2014 which states that in Gorkha, thatch roofs were used by 17.5 percent of dwellings, and stone roofs were used by 60 percent. The physical capital was measured by changes in construction and access to physical capital, construction efficiency, and increased knowledge of community development activities. Each of these indicators had an average score of 0.961, 0.964, and 0.923, respectively. Physical capital received an average total score of 0.951. The variables chosen to evaluate human capital were user group awareness of roles, changes in leadership capability, and level of knowledge and skills in forest management, which received average scores of 0.832, 0.782, and 0.629, respectively. 0.748 was found to be the average total score for human capital.

According to Ohler, 2003, after seven years, Nepal's vegetation cover increased from 32% in new sites to 90% which is supported by this study in Gorkha. The enhancement in greenery and landscape beauty, ease in accessing forest resources, the incidence of forest fire, encroachment, and drying up of water resources were used as indicators to assess the status of natural capitals, which gained average scores of 0.456, 0.578, and 0.732 respectively. This capital received an average total score of 0.589. SEEPORT, 2014 also concludes to improve the land use and productive composition of leasehold plots significantly, and the time spent collecting fodder and forages has continuously decreased by 45 percent (SEEPORT, 2014).

As like the finding by Ohler, 2003, our study concludes the positive impact of LHF to increase income and strengthen the financial aspect of people. Financial capital received an overall score of 0.722 (Increase in employment opportunities: 0.702, income from

collection of forest products: 0.696, and Loan provisions for activities that generate income (IGAs):0.768). LFUGs have changed their subsistence farming to commercial agricultural production. According to Baral and Poudyal (2012), bananas and pineapples were the major sources of income in Gorkha but our study showed that the major income sources were from livestock rearing and vegetables. Livestock farming has become more popular in LHFUGs which showed a similar finding to Laudari, 2014. Micro saving and credits were found to be popular, and also participation in saving and credit activities has increased.

CONCLUSIONS

The result has found the positive role of leasehold forestry programs targeting the pro-poor. In total, all five capitals have shown a positive value that indicates their progression due to the LHF program. Construction and access to physical capital, particularly improvements in construction efficiency and knowledge of community development, were the most important achievements. This study adds evidence to better-managed natural resources can help achieve both conservation and livelihood options. It supports the recommendation by CIFOR, 2019 that states integrating forestry into livestock programs based on a landscape approach promotes environmental sustainability with generation of initial income through a multidisciplinary and holistic approach to poverty alleviation. The role of extension services is also important in helping marginalized households to implement forest restoration and green income-generating activities in order to promote conservation and sustainable development. The challenge is to strengthen local governance and motivate the involvement of real backward people. Finally, we recommend the capacity building of frontline technicians and local people for better achievement of the goal.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

The Effect of Mycorrhiza Inoculation on Pepper Plant Growth and Mycorrhizal Dependency

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ABSTRACT
Pepper cultivation is one of the vegetables that are widely produced in the world. The use of mycorrhiza in sustainable agriculture can be an environmentally friendly and economical agriculture strategy. The purpose of the study; is to investigate the effect of mycorrhiza inoculation on plant growth development, yield and mycorrhizal dependency. The hypothesis to be tested is; inoculation of mycorrhiza increases pepper plant growth parameters. The experiment was established as a pot experiment under greenhouse conditions in February 2018 and harvested in April 2018. BT 16-90 F1 pepper (*Capsicum annuum* L.) species seeds were used with mycorrhiza *Claroideoglomus Etunicatum* and without mycorrhiza inoculation with three replications. Before harvesting, plant height and leaf diameter were measured. At harvest, the dry and fresh weights of the root and shoot were measured. In addition, some of the root morphological properties (like root diameter, root length, root surface area and root volume) were determined by using WinRhizo program. In addition, mycorrhizal root infections were determined. Mycorrhizal dependency was calculated by using dry matter data. Research findings showed that mycorrhizal inoculation increased pepper plant root, shoot fresh and dry weight, plant height, and leaf diameter. In addition, the root length of the plants with mycorrhiza inoculation (as 3921 cm pot^{-1}) was higher than without mycorrhiza (with 1945 cm pot^{-1}) treatments. The pepper plant has a high mycorrhizal dependency (71.9%) with *Cl. Etunicatum* inoculation. The results shown that *Cl. Etunicatum* inoculation increased pepper plant growth and development. Also, the pepper plant is a highly mycorrhiza-dependent plant.
Keywords: Pepper, Mycorrhizal Dependency, Shoot and Root Growth

INTRODUCTION

Pepper is very important produced vegetables in world. It is a plant with numerous varieties. Initially, it originated from Americas; but recently pepper has cultivated to Asia, Africa and Mediterranean. Pepper was commonly used for medicinal purposes and its usage and cultivation may be around 5000 years ago as historically (Moreb et al., 2020). Pepper is a rich source of carotenoids, phenolic compounds, and antioxidants. Moreover , a medium-sized pepper be able contain up to 200% of a person's daily requirement of vitamin C (Hallmann & Rembiałkowska, 2012). In addition, pepper contains many nutrients for instance; fibers, fats, proteins and carbohydrates and micro elements such as Zn, Cu and Fe (Ananthan et al., 2014, Moreb et al., 2020). Due to the abundance of these, there were so many studies have focused on the health benefits of consuming pepper (Clark & Lee, 2016, Moreb et al., 2020, Wang et al., 2006). Pepper plants are commonly used in food, medicine and paint industries (Aybak, 2002). Previous studies also showed that pepper plants are mycorrhizal dependent (Baum et al., 2015, Ortas et al., 2011, Sensoy et al., 2007).

Mycorrhiza which live mutualism with around 80% of terrestrial plants (Egerton-Warburton et al., 2005), provide plants with water and nutrients (Khan & Rao, 2019), as well as resistance to diseases and pests, resistance to drought stress and increased the plant growth (Smith & Read, 2010). Moreover, there are various studies showing that mycorrhiza inoculation increases pepper growth (Douds Jr & Reider, 2003, Ortas et al., 2011, Sensoy et al., 2007). Plants have a good root and shoot system to get more nutrition and photosynthesis. These days, it has great importance to use natural resources in agriculture in a sustainable way. Therefore, using a sustainable resource such as mycorrhizal fungi in agriculture can prevent excessive fertilizer use and will also be more economical and eco-friendlier.

Although there are studies in the literature about the effect of mycorrhiza inoculation on pepper growth, we still do not have enough information about the effect of mycorrhizae on pepper as compared to other commercially important crops (Al-Karaki, 2017). In this respect, the aim of the study; is to investigate the effect of mycorrhiza inoculation on plant growth development,

yield and mycorrhizal dependency of pepper plants. The hypothesis to be tested is; inoculation of mycorrhiza increases pepper plant growth parameters.

MATERIALS AND METHODS

The experiment was established in February 2018 in Department of Soil Science and Plant Nutrition Research and Application Greenhouses, Cukurova University Faculty of Agriculture. BT 16-90 F1 pepper variety was taken as the host plant and (*Cl. Etunicatum*) was used as the mycorrhiza species. Andesitic tuff (Urgup stone) + soil (Menzilat soil series) was used as 9:1 volume ratio for growing medium in the experiment. The experiment was established in three replications with mycorrhizae (+M) and without mycorrhizae (-M) according to the completely randomized design (CRD) of experiment. In order to eliminate microorganisms that may compete with mycorrhizae in the medium and to better see the effectiveness of mycorrhizae, the growing medium used in the research was autoclaved for sterilization purposes in an autoclave at 120^0C under 2 atm of pressure for 2 hours. 2 L of pots were use in the experiment and harvested in April 2018. Before harvesting, the height of the plants and leaf diameters were measured. Immediately after harvest, wet and dry matter yields of root and shoot of the plants were taken. In addition, plant root morphological characteristics were analyzed using WinRhizo program and root infection was performed according to Koske and Gemma (1989). With the data obtained, Mycorrhizal Dependence (MD) was calculated according to (Ortas, 2012). Formula of MD is shown in equation 1. ANOVA analysis and LSD test were made with JMP 8 package program. Origin 2022 package program was used for correlation matrix of variates in Figure 6.

$$\text{MD}= \frac{(+M)\ Dry\ Weight - (-M) DryWeight}{(+M) Dry\ Weight} x100$$

(Equation 1)

RESULTS AND DISCUSSION

Effect of Mycorrhiza Inoculation on Pepper Fresh and Dry Weights

Figure 1 shows how mycorrhizal inoculation affected the fresh weight of the pepper's root and shoot. Both Table 1 and Figure 1 shown that mycorrhizal inoculation significantly improved the fresh weight of pepper root ($P<0.01$) and shoot ($P<0.05$). As presented in Figure 1, the fresh weight of the root and shoot that received +M pots (with 8.9 g pot^{-1} and 3.2 g pot^{-1}) was statistically higher than that of the control group (with 7.7 g pot^{-1} and 3.0 g pot^{-1}) without mycorrhiza. As seen in Figure 6, there was strong positive correlation ($r = 0.93$) between root infection and root fresh weight, as well as there are also positive correlation ($r = 0.91$) between root infection and shoot fresh weight. Mycorrhiza inoculation was expected to increase pepper fresh weight. There are many studies in the literature that mycorrhizal fungus enhances pepper growth. For example; Haghighi and Barzegar (2018) reported that mycorrhiza inoculation increased pepper growth in their study. Moreover, Balog et al. (2017) reported that mycorrhizal inoculant improved plant yield in their study.

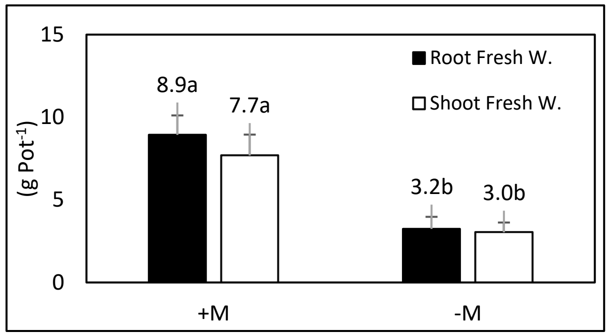

Fig. 1. Impact of mycorrhizal inoculant on fresh weight in different parts of pepper (root and shoot)

Figure 2 shown how mycorrhizal inoculation affected the dry weight of the roots and shoots. In comparison to plants without mycorrhiza inoculation, plants with mycorrhiza inoculation demonstrated a statistically significant difference as pepper dry matter. Moreover, +M plants had greater increases in shoot dry weight than -M plants. Root dry weights for +M and -M had 0.59 g pot^{-1} and 0.17 g pot^{-1}, respectively. Mycorrhizal fungi are known to improve yield by giving the host plant nutrients and water. Our research findings, are supported by Hegazi et al. (2017) study that mycorrhizal inoculation enhanced pepper dry matter. In addition, Ortas et al. (2011) in their study investigated the impact of different mycorrhiza, P and Zn applications on pepper P and Zn uptake under greenhouse conditions. The research findings of the study showed that mycorrhiza inoculation was increase pepper dry matter yield and the study supports our research findings. Furthermore, there was a positive strong correlation ($r=0.96$-0.99) between dry and fresh weight of pepper in Figure 6. The relation between dry weight (root and shoot) and mycorrhizal infection is also observed to be positive and high ($r = 0.94$-0.97).

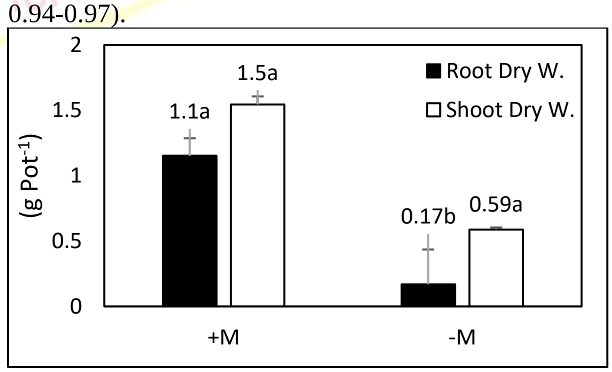

Fig. 2. Impact of mycorrhizal inoculant on root and shoot dry weight

Impact of Mycorrhiza Inoculation on Pepper Plant Height and Leaf Diameter

It is seen the impact of mycorrhizal application on height and leaf diameter of pepper in Figure 3. The height and leaf diameter of plants having mycorrhizal innoculation

were statistically more than non-mycorrhiza inoculated plants (for the height P>0.001 and for the leaf diameter P>0.01) in Table 1. Mycorrhiza inoculation increased pepper plant height by 26.6% and leaf diameter by 16.6% as seen in Figure 3. It is expected that mycorrhizal fungi, which increase plant yield and nutrition, also increased some plant morphological characteristics such as plant height and leaf diameters. Temperini et al. (2008) show that inoculated different pepper varieties with mycorrhizae and measured some plant yield and growth parameters in their work. In this study, mycorrhiza inoculation generally increased pepper height and leaf number and their study supports our research findings. In addition, there are positive correlation between mycorrhzal infection and pepper plant height and leaf diameter (r= 0.98) as seen Figure 6.

Table 1. Level of significance for effects of increasing phosphorus doses application on fresh weight, dry weight, plant height and leaf diameter, root morphological properties (like diameter, length, surface area and volume), root infection and mycorrhizal dependency.

Root Fresh W.	Shoot Fresh W.	Root Dry W.	Shoot Dry W.	Total Dry W.
**	*	**	*	**
Plant Height	Leaf Diameter	Root Infec.	Root Diameter	Root Length
***	**	*	ND	*
Root Surface A.	Root Volume	M. Dependency		
ND	ND	-		

NS, not significant. *, ** and *** show significant level at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$.

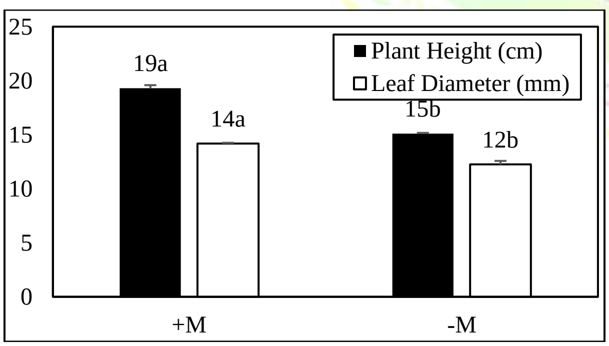

Fig. 3. Impact of mycorrhizal inoculation on height and leaf diameter of pepper

Effect of Mycorrhiza Inoculation on Pepper Root Morphological Properties

It is seen that no statistically difference (P>0.05) as diameter, surface area and volume of root when the effect of mycorrhiza inoculation on some root morphological features of pepper is evaluated (Table 2). However, Tables 1 and 2 show that there was a statistically significant variation in root length. As statistical, +M had a root length of 3921 cm pot^{-1}, which was longer than -M's root length of 1945 cm pot^{-1}, as shown in Table 2. Several studies had shown that the mycorrhizal fungus improved plant root development, particularly root length. Zhang et al. (2017) demonstrated that with mycorrhizal plants have longer roots than without mycorrhiza plants, and their research findings support our study.

Table 2. Effect of mycorrhiza inoculation on pepper root morphological properties

Application	Diameter (mm)	Length (cm pot^{-1})	Surface Area (cm^2 pot^{-1})	Volume (cm^3 pot^{-1})
+M	0.40±0.1	3921±122a	566±23.2	5.11±1.7
-M	0.67±0.1	1945±32b	510±56.1	6.90±1.3

Effect of Mycorrhiza Application on Pepper Root Infection

It is seen effect of mycorrhizal inoculation on root infection in Figure 4. There was no statistically significant difference in mycorhizal infection. However, the average root infection of mycorrhiza-inoculated plants was 40% while the average root infection of non-mycorrhiza inoculated plants was 10%. It's possible that the researchers' sloppy work methods contributed to the 10% infection in plants that weren't treated with mycorrhizae.

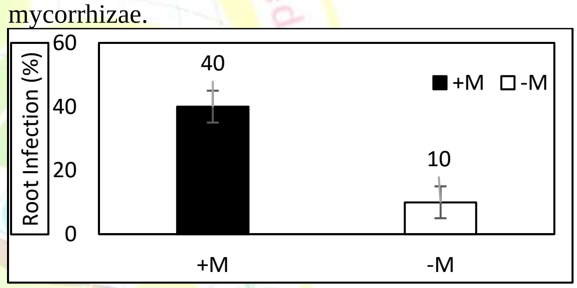

Fig. 4. Impact of mycorrhiza inoculation on pepper root infection (%)

Mycorrhizal Dependency of Pepper

Figure 5 shows that impact of mycorrhiza application on pepper growth. The average mycorrhizal dependence is 71.9 %. There are studies in the literature indicating that pepper is a MD plant (Beltrano et al., 2013, Ikiz et al., 2008). Moreover, according to Ortas et al. (2011) pepper is a MD plant. Moreover, Pınar et al. (2015) described that the pepper is a MD plant.

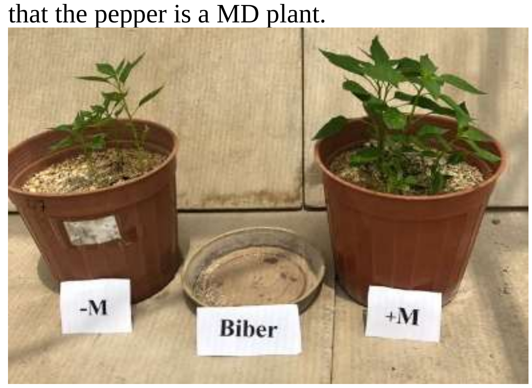

Fig. 5. A picture from effect of mycorrhiza inoculation on plant growth

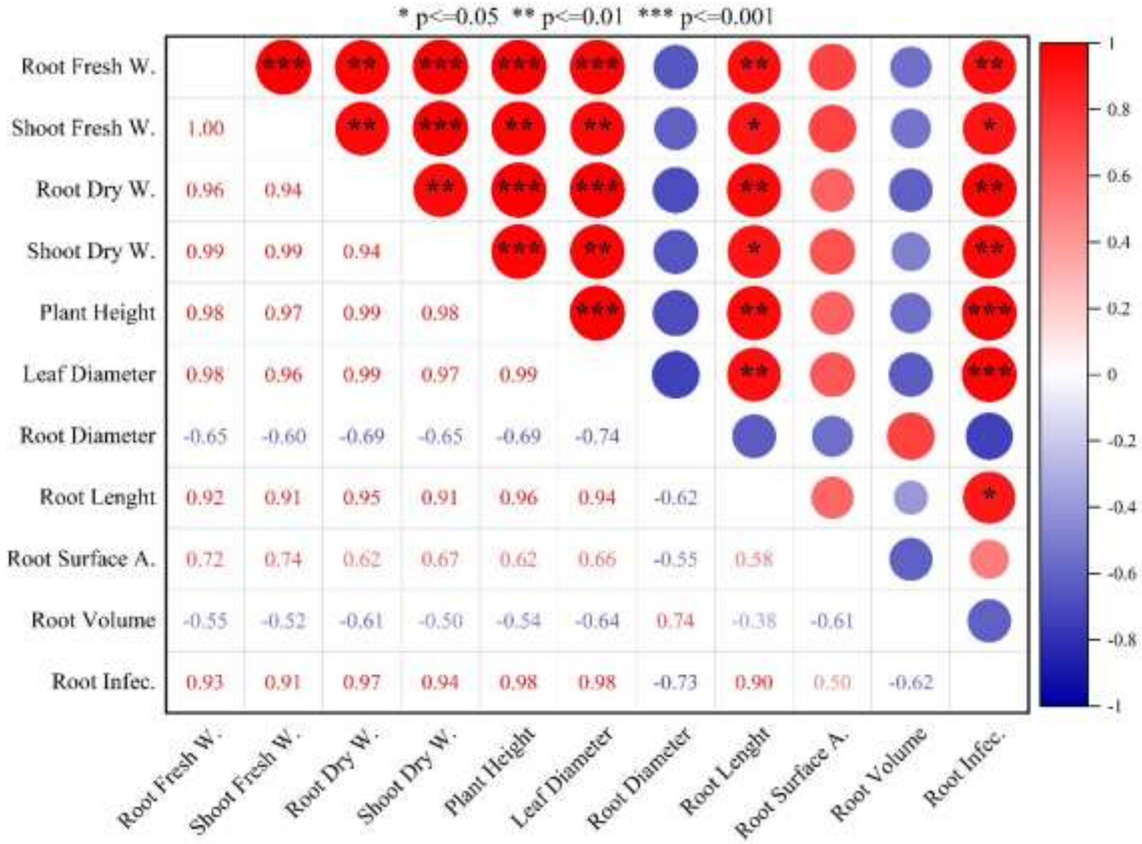

Fig. 6. Correlation matrix of variates

CONCLUSIONS

The research findings of the study proved that mycorrhizal inoculation improved various morphological traits of the portions of pepper's root and shoot, and also its fresh and dry weight yields. Our idea is therefore supported by the research outcomes of our investigation. Additionally, because the pepper plant depends on mycorrhizae for growth, mycorrhiza inoculation can be used in pepper cultivation to rise production in a sustainable and profitable way.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Review Article

The potentiality of GIS for assessing soil pollution – A review

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ABSTRACT
The assessment of soil pollution is only one instance where geographic information systems (GIS) have shown to be an invaluable tool in environmental management and assessment. Globally, there is growing worry over soil pollution since it can have catastrophic repercussions on plant, animal, and human life. A more in-depth understanding of the scope and severity of contamination is made possible by GIS, which offers a flexible and all-encompassing method to studying and assessing soil pollution. With the aid of GIS technology, precise maps of soil contamination may be produced by combining data from numerous sources, such as remote sensing, aerial photography, and ground surveys. This information can then be evaluated using a variety of techniques, such as spatial analysis, to pinpoint polluted areas, possible sources of pollution, and the effects they are most likely to have on the environment and human health. By making it easier to identify sensitive regions that need additional research or remediation, GIS can also help with the analysis of the risk of pollutant movement and dispersion. Comparing GIS to conventional methods for assessing soil pollution has various benefits. First of all, it enables a more thorough and in-depth examination of the degree and breadth of contamination, enabling the identification of locations that need urgent care. Second, it makes it easier for different stakeholders, such as environmental agencies, researchers, and policymakers, to share data and information, enabling better decision-making. Thirdly, it makes it possible to monitor and control soil contamination more effectively, allowing for the early detection of potential issues and the implementation of suitable corrective actions. In general, GIS technology is a useful tool for assessing soil pollution since it offers a more thorough and knowledgeable approach to environmental management. It is a crucial tool for environmental experts engaged in the assessment and control of soil pollution due to its capacity to combine different data sources, perform spatial analysis, and promote information sharing.
Keywords: GIS, soil pollution, contaminants, risk assessment, mapping.

INTRODUCTION

For organizing and evaluating data about soil pollution, geographic information systems (GIS) are a crucial tool. Environmental agencies are gathering a growing amount of data, and GIS can assist in organizing and visualizing this data to make it simpler to interpret and use in decision-making (Kamariddinovich and Rakhimjonovna 2023). In this post, we'll look at how GIS is used to manage soil pollution and explore some of its practical uses. A severe problem that affects both the environment and human health is soil pollution. It happens when pollutants are dispersed into the soil by either natural or artificial methods. Industrial operations, agricultural practices, and waste disposal facilities are just a few of the sources that might produce contaminants. Heavy metals, pesticides, herbicides, and other chemicals that may be hazardous to human health as well as to plant and animal life can be included (Gautam et al., 2023). Data about soil pollution are manipulated and estimated in several ways using GIS. The mapping of soil pollution is one of the most significant uses of GIS. For environmental authorities and decision-makers, GIS can help to provide detailed maps of the scope and severity of soil pollution. Environmental agencies can quickly and readily identify locations that need additional research or cleanup by producing maps that show soil pollution data (Neeraj et al., 2023). Data on soil pollution can also be examined using GIS. GIS can assist in identifying patterns and trends in soil contamination by combining data from many sources, such as soil samples, water quality data, and land use information. As a result, environmental agencies may be better able to comprehend the origins and consequences of soil pollution and create preventative and corrective measures (Abuzaid et al., 2023). Risk assessment is a significant GIS application in soil pollution management. GIS can help to identify places and populations that are at risk from soil contamination by fusing data on soil pollution with details on the susceptibility of various ecosystems and groups. As a result, decision-makers may be better able to focus

resources where they are most required and prioritize remedial activities (Jin et al., 2023). One of GIS's most potent features is its capacity to combine data from numerous sources. GIS can present a thorough picture of soil contamination in a specific area by combining data from soil samples, water quality assessments, land use data, and other sources. Taking into consideration a variety of elements and variables, this can assist environmental agencies in making judgments about how to control and remediate soil pollution (Liu et al., 2023). Additionally, the transport and dispersion of pollutants in soil can be modeled using GIS. GIS can mimic the spatial distribution of soil contamination and soil contaminants by utilizing computer modeling approaches (Patel et al., 2023).

The main objective of this article is to overview the potentiality of GIS in assessing soil pollution.

Soil pollution

Due to the rise in soil contamination over the past few decades, both human and environmental health may be at danger. The main causes of soil pollution are human activities, which cause contaminants to accumulate in soils to potentially dangerous levels. Soil pollutants include a wide range of contaminants (both organic and inorganic substances) that are either created as a result of anthropogenic activity or are naturally present in soil. Monitoring soil quality may be difficult due to the absence of definite monitoring indicators and parameters. On the other hand, issues related to the expansion of the world's population are continuously putting pressure on soil quality and the necessity of long-term soil fertility. Soil contamination has become a prominent topic due to the intersection of all the aforementioned issues (Cachada et al., 2018). Soil is considered as the pillar of the agricultural ecosystem and significant store for organic materials which able to absorb the dangerous components (Anawar and Chowdhury 2020). The decrease in soil productivity brought on by the presence of pollutants in the soil is known as soil pollution. As stated by Weissmannová and Pavlovsk (2017), it might also be a persistent problem for agricultural usage that is influenced by the safety of the food and water ingested. Heavy metal poisoning of soil is an issue for food chains and public health, particularly in mining zones. Numerous studies centered on evaluating the risk of soil pollution and its spread from mining regions to the surroundings as well as employing supplemental data to map soil heavy metals (Zeng et al., 2021). Soil contamination is the presence of some compounds in soil as a result of human activities. These contaminants can harm fundamental soil structures, decrease soil quality, and have a negative impact on the health of both people and the environment. Many nations have identified soil contamination as a major national concern on how it impacts agricultural land and people's health (Luo et al., 2015). For instance, there are several events and protocols were established and created which have specific provisions acknowledging the significance of soil contamination and degradation in Asia today (MEP-PRC, 2016). Similar to other countries, the main heavy metals' sources in the world's include urbanization, transportation, waste disposal, industrial activity, power generation, agriculture, including fertilization and animal feeding additions, and mining as well as smelting. There are some locations with significant levels of soil contamination near point sources, such as mines and smelters, which raises serious but primarily limited concerns. Despite having lower contamination levels than other situations, including agricultural soils, they are nonetheless important as a direct channel for contaminating food (Zhou et al., 2014). Another example of a relatively small nation is the UK, which has a very diversified geology, heavy metal mineralization in certain regions, where a long-term mining activity cause soil pollution. Polluted areas have been addressed through the development planning process ever since the current soil system in the UK (Luo et al., 2009).

Types of soil pollution

Chemicals or other contaminants that are hazardous to living things can pollute soil. Pollutants harm the soil structure, lower its quality, and cause different types of the soil erosion. The pollution sources and its impact are utilized to differentiate between soil contamination types. The main types of soil contamination are such as the agricultural pollution, environmental wastes, and urban activities (Gautam et al., 2023).

Agricultural pollution

Through the application of fertilizers, agricultural operations improve crop yields but simultaneously polluting the soil and degrading its quality. By contaminating the soil, pesticides can affect plants and animals. These substances contaminate the groundwater supply by penetrating deeply into the soil. These pollutants collect in other places and damage the local water supply through irrigation and rain runoff. About 90% of contamination is caused due to the environmental wastes which inappropriate disposal causes the soil to become contaminated with dangerous chemicals that have an adverse impact on local flora and animal environment, water resources, as well as the fresh water. Chemicals found in toxic vapors from landfills have the potential to go back to the environment as the acidy rains which harm the appearance of agricultural soil (Yuan et al., 2023).

Pollution by the urban activities

Soil pollution can result from human activities both directly and indirectly. Inadequate drainage and increasing runoff cause nearby land areas or waterways to become contaminated. When waste is not properly decomposed, it accumulates in soil and cause pollution which can reach the groundwater. Bacteria are more effective soil microorganism which regenerated by the wastes' decomposition and produce methane and increase the global warming and negatively affect the air quality (Adedeji et al., 2019).

Soil pollution causes

Human activities affect the soil and lead to soil pollution. The pesticides and fertilizers are much linked to the soil pollution. Additionally, pesticide/s used on plants have the potential to penetrate into the ground and have a long-lasting impact. In turn, several potentially dangerous compounds present in plants may build up. Fertilizers, like cadmium, are used at amounts that are toxic and kill crops. By using contaminated water to irrigate crops or by using mineral fertilizers, heavy metals can penetrate the soil. Landfills, bursting underground bins, and sewage system leaks can all release toxins into the surrounding soil. Both natural and man-made processes can produce heavy metal contamination. Large discrepancies in mineral content among the surface layers of an organic soil and the lower horizons of the soil profile can result from natural processes such bioaccumulation in vegetation (Weber and Karczweska 2004). The acidy rain is considered as one of the most effective causes of the soil pollution. It is produced when industrial gases combine with precipitation on soil structure. Iron, steel, energy, and different chemicals manufacturing that carelessly treat the area as a wasteland leave enduring evidence for years to come. Vehicles that have been washed by rain may spill fuel, contaminating any nearby land. The soil erosion occurs when soil particles move by water as well as wind and cause lose in the soil structure and nutrients. Here are some soil pollution causes: (1) industrial liquid and solid wastes, such as toxic solutions, gases and also different chemicals; (2) Solid and liquid agricultural materials such as pesticides, insecticides and fertilizers; (3) poor system of the soil management; (4) improper techniques of irrigation; (5) the frequent and continuous leakage of sanitary waste; (6) toxic fumes from industries mix with rain to cause acid rain; (7) fuel spills are washed out of cars by precipitation and aeration; (9) The use of pesticides in agriculture keeps chemicals in the environment for long time; (10) the lack of a proper garbage disposal system causes garbage to spread into the soil; and (11) the improper disposal of nuclear waste contaminates the soil and has the potential to cause mutations (Woejko et al., 2020).

The impacts of soil pollution

Because of contacting with the polluted soils either directly or indirectly, human health as well as the ecological equilibrium are affected. Moreover, soil pollution impacts are dangerous on Earth's creatures. Infected soil frequently prevents crops from growing and thriving. Any cultivated crop in the contaminated soils can absorb harmful chemicals which provide a health risk to anyone who consumes them (Qin et al., 2021). Increased soil salinity can be a symptom of several types of soil contamination. The soil becomes unfit for plants in this circumstance and frequently turns useless and arid. Earthworms as important soil organism can perish where soil pollution alters the soil's structure. Besides the ability to enhance creatures' life, soil contamination can also change the structure of the soil, which can have an impact on large predators like birds (Pathan et al., 2020). The intake of foods cultivated in polluted soil causes health concerns, which has serious repercussions for human health. The genetic make-up of the body is altered by prolonged contact to contaminated soil, which increases the risk of prenatal disorders and chronic health problems. Heavy metals, gasoline, solvents, and agricultural chemicals can all cause cancer after prolonged exposure. Organophosphates have the potential to set off a series of events that result in neuromuscular obstruction. In their study, Mishra et al. (2016) concentrated on determining how pollution affects plant development. They noted that (1) the balance of the ecosystem is impacted by soil pollution; (2) Plants frequently cannot adapt to a change in soil chemistry in a short period of time; (3) Microorganisms present in the soil deteriorate and cause additional soil erosion problems; (4) soil pollution negatively affects the soil fertility and suitability for cultivation; (5) Polluted land cannot support the majority of life forms that depend on soil fertility; (6) Fruits and vegetables grown in polluted soil lack essential nutrients. They may be poisonous and cause serious health issues for those who consume them; (7) landfill emissions of poisonous gases and unpleasant odors negatively affects the human health as well as the surrounding environment; (8) death of several affected organisms such as earthworms may be due to the soil pollution whereas this phenomenon makes other predators affect the soil environment. Hou and Li (2017) noted that there are complexity and variability in the soil pollutants. This is due to the contributions from parent material and other anthropogenic activities like agricultural as well as atmospheric inputs.

Geographic Information System (GIS)

It is a computerized software/program which can stores, controls, examines, as well as presents spatial information. The professionals in several science fields use and rely on GIS since the 1970s. Additionally, GIS is an essential tool which can be used for normal operations in governmental and non-governmental organizations. Several services which depend on the spatial information as well as the location-based data such as the web mapping and in-vehicle navigation are perfect examples of using not only GIS but also other integrated tools such as the Internet, GPS and wireless technology.

The USD of Labor has assigned the GIS technologies as a sector with strong growth potential (Chang, 2008). There are numerous definitions for geographic information as well as the processes which utilized in storing, retrieving and displaying the spatial as well as the geographic information. In this article, general definition is provided which based mainly on the developed information system to manage different types of the data resources in several fields of application and utilization as well as research (Goodchild, 2018). A geographic information system is an integration of modern technology and tools including software,

hardware, information/data, people/users, and organizations/institutional frameworks. The GIS is used to collect, store, analyze, and disseminate information on geographical areas of the planet (Ali, 2020).

GIS Components

Like other information technologies, a GIS needs certain components in order to function. A GIS is made up of five fundamental components: technology, software, data, people, and methodologies.

Hardware/Equipment

Computers are used for data processing, storage, input, as well as output, product or service. Several hardware facilities such as the printers and plotters are utilized to produce the output reports and maps. In addition, the different kinds of the digitizers, scanners, and photocells can be used to rectify and digitize the spatial information. The GPS instrument' data as well as the mobile devices are utilized for the field work.

Software/Programming

GIS software, whether it is open source or commercial, consists of computer programs and applications that are used to manage data, perform data analysis, display data, and perform other functions. GIS can leverage additional programs created in C++, VB.NET, JavaScript, or Python for particular data analytics. Menus, icons, and command lines are often used user interfaces for these programs and apps while running on an operating system like Windows, Mac, or Linux.

Data

The several types of the data are very important component of a GIS. A GIS use the database management system (DBMS), which is applied in many organizations in order to organize and preserve the information/data. The main two types of the geographic data which can be used in the GIS are vector and raster data. These types of data are considered as data layers in the GIS work environment which can be presented as points, lines, and polygons.

Users/People

GIS experts determine the goals of using GIS, interpret the data, and communicate the findings. GIS tools cannot be used without the users who manage, use and develop the applied methods to solve the different issues. Users of GIS include those who use it to facilitate their daily work as well as the technical professionals who developed and maintain the system. End-users are persons who use the GIS tools to achieve the aim of the organization or a specific project/program.

Methods

An effective GIS adheres to several kinds of plans and businesses, which are considered as components of frameworks and model-specific activities. A methodical way to measure a variety of geographical activities and events is the geographic information system. To highlight geographical themes, entities, and relationships, use a computer database to represent these measurements. By merging several sources, use these representations to create more measures and discover fresh relationships. These representations should be altered to work with other sets of relationships and entity systems. The institutional and cultural context in which these people operate is reflected in their actions. GIS is essentially a collection of computer programs for organizing data geographically. The fact that it may combine ideas and procedures from other fields, such as mapping, geography, surveying, statistics, and operation research approaches, as well as mathematical and statistical processes which makes it more flexible for managing the spatial and geographic information. By creating a direct relationship of the spatial and non-spatial kinds of information, it is able to conduct an integrated analysis. Spatial data, which are essentially mapped databases, includes charts, aerial photos, satellite images, maps that have been surveyed from a plane table, and observations from the Global Positioning System (GPS). The attribute or non-spatial data can be discovered as words, numbers, or symbols in secondary surveys, the census, and other sources. Moreover, the maps are generated using different methods and GIS tools which can be utilized in different projects. Either manually utilizing the scanned images or automatically using a raster to vector creator can create the map. These digital maps could be produced by any survey company or derived from satellite photos (Ali, 2020).

Organization

Operations involving GIS take place in an organizational setting. As a result, people need to be included in the organization's culture and decision-making processes when it comes to things like role and value (Chang, 2008).

The Role of GIS in assessing soil pollution

Recent developments in digital technologies have increased the number of applications and the growth of GIS, which has profited from GIS as an important partner technology for the evaluation of crops, soils, and their habitats. In recent decades, the application of GIS in agriculture has expanded significantly. The entire agricultural value chain makes use of GIS. To characterize different kinds of factors affecting a specific phenomenon, the researchers use several GIS tools and features. There are many soil applications can be done using GIS such as spatial variability distribution of different soil properties such as texture, groundwater table, fertility, pollution, hydraulic conductivity, slope, electrical conductivity, climatic conditions, topography, land use/land cover, biotic and abiotic stresses, and etc. In order to increase agricultural productivity and profitability through accurate techniques, it is increasingly important to provide the necessary spatial and geographic data (Shan et al., 2013). Environmental and public health data can considerably benefit from GIS (Tim, 1995). An important consideration is the relationship between geographic and descriptive information. Consider a set of spatial data represent several areas or cities which can be connected by a table, include area's name, its population, etc. These systems provide details on the data related to the location where

it is gathered, managed, stored, processed, and visualized in a digital setting. This information are commonly known as cartographic, geographic, or spatial data. They might also be related to a variety of characteristics that characterize them as unique (Fradelos et al., 2014). Through continuous progress, GIS has considerably expanded geographic research and applications over the past 50 years, and has advantages for other subjects like Earth System (Goodchild, 2018). Gathering geographic data, identifying and characterizing the earth objects are the main goals of GIS (Lin et al. 2013). This helps to explain why GIS has become more and more popular in contemporary society (Goodchild and Glennon 2008). By providing users with a logical framework for understanding spatiotemporal distributions and interactions, the geographical analysis integrated with other tools and data sources such as the statistical analysis' tools and the spatial data has made the applications of the GIS expanded far from the initial domain of mapping. GIS is used for identifying either physical or social dynamic spatial phenomena globally (Kosiba and Bauer 2013). However, not all phenomena or objects can be identified using the tools of GIS (Lü et al., 2019). All human activities are connected to the GIS applications. The online nautical maps encourage secure canal navigation by using routing and scheduling. Additionally, surveying is the process of locating an object on the earth's surface. Calculating angles and distances between various points on the surface of the earth is a necessary step in a land survey. Geologists utilize GIS for a wide range of objectives, but there are many other applications for it in the science. analyzing seismic data, investigating soils and strata, assessing geologic features, or creating three-dimensional (3D) visualizations of geographic features. Planning as well as social development employ GIS, and the GIS helps to distinguish the world challenges. Today's GIS technology is rapidly evolving and providing a wide range of new planning possibilities. In order to achieve sustainable tourism development, the GIS is also used in the tourist information system. The detection, risk assessment, and early warning of global earthquakes are all potential functions of the GIS. Additionally, GIS is utilized for fisheries and ocean industries, the development of public infrastructure facilities, and energy consumption tracking and planning. GIS helps managers organize and spatially visualize space to decide how it should be used. All agricultural activities make extensive use of GIS tools. GIS may be very helpful in evaluating soil capability, productivity, appropriateness, and fertility as well as mapping all soil properties and issues thanks to its data processing and transfer capabilities. According to Rathinavel et al. (2023), the GIS is also utilized for pesticide administration, crop protection, and the detection of biotic and abiotic stressors on plants. Information management will be crucial to improving farming methods in the upcoming decades. It makes logical to arrange farm information in spatial databases since agricultural processes are fundamentally geographical. Patchiness in the presence and dispersion of plant pathogens and disease is typical due to the geographical variability brought on by the biological and physical characteristics of agricultural systems. Plant disease management techniques can be improved by employing GIS to provide epidemiological data in the same way as other farm data (Fischer et al., 2019). In another study, the GIS tools were used to identify, detect, measure, analyze, and map incidents of environmental injustice, which is the related to environmental threats (Maantay, 2002). Additionally, the GIS used to evaluate the spatial variability of some hazards' sources (Brtnick et al., 2020). The detection of soil issues is proven to be successful with the integration of GIS and remote sensing (Iu et al., 2020). Due to the fast-industrial expansion and urbanization, toxic metals affect the agricultural soil poses a serious danger to both public health and ecological safety. Numerous studies have been conducted in this area. For instance, Bhuiyan et al. (2021) evaluated heavy metal deposition, spatial enrichment, environmental risk, and source allocation in certain soils of Bangladesh using a GIS. More than 90% of these soils exhibited higher concentrations of Cr and Cd. Similar to this, several investigations confirmed the contamination in various areas of Bangladesh due to excessive content of toxic metals in the water and rivers' sediments as well as some different industrial areas. In order to investigate the spatial variability of the heavy metals (Mn, Fe, Zn, and Cu) in various soils of Iran and identify soil pollution hotspots, Keshavarzi et al. (2022) employed GIS methodologies employing geo-statistical interpolation methods. El-Rawy et al. (2020) calculated the heavy metal concentrations to assess the risk of soil pollution in Egypt's Minya Governorate. They gathered 159 soil samples for that purpose, which were tested for the content of Mn, Zn, Cu, Fe, and B. While measuring the hazardous (As, Cd, Co, Ni, Se, and Pb) and heavy metal elements in the collected samples, the applicable pollution indicator was utilized. Geostatistical techniques were employed to identify the sources and concentration hotspots of the heavy metals deposited in the examined soil.

CONCLUSIONS

Finally, it should be noted that Geographic Information Systems (GIS) are essential for evaluating soil pollution. They offer a useful resource for gathering, processing, and visualizing geographic information about soil contamination. GIS enables researchers and stakeholders to acquire a thorough picture of the quantity and distribution of soil pollution by integrating diverse data sources, such as soil sampling data, land use data, and environmental monitoring data. Researchers can use GIS to produce intricate maps and models that show hotspots of soil contamination, pinpoint potential sources of pollution, and evaluate the dangers of polluted soil. Decision-makers can use this geographical analysis to build regulatory frameworks, prioritize locations for

cleanup operations, and assess how well environmental management policies are working. The collaboration and information exchange between various stakeholders, such as scientists, policymakers, and communities, is also made easier by GIS. This improves the openness and accountability of assessments of soil pollution, enabling more informed decision-making and public participation in environmental management. It's crucial to recognize the GIS's limits when evaluating soil pollution, though. The quality of the input data, the availability of field verification, and the choice of the best analytical techniques all have a significant impact on the accuracy and dependability of the results. To enable thorough and accurate soil contamination evaluations, GIS must be integrated with other scientific methods and knowledge. In conclusion, GIS is a useful tool for evaluating soil pollution because it gives users a spatially explicit understanding of contamination patterns, directs decision-making, and promotes efficient cooperation among stakeholders. The ability to control and mitigate the effects of soil contamination on human and environmental health will continue to improve with continued improvements in GIS technology and data collection methods.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

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Influence of plant growth retardants on morpho-physiological parameters and yield of pigeonpea (*Cajanus cajan* L. Millsp)

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ABSTRACT
The field experiment was conducted at Agricultural Research Station, Bheemarayanagudi, during *Kharif* 2021- 22 to know the influence of plant growth retardants on morpho-physiological and yield parameters in pigeonpea. The experiment was laid out in randomized complete block design and replicated three times with eight treatments including control, nipping at 60 DAS, mepiquat chloride @ 1000 ppm, thiourea @ 1000 ppm, chlormequat chloride @ 1000 ppm, daminozide @ 1250 ppm, ancymidol @ 1000 ppm and paclobutrazol @ 150 ppm were applied through foliar application at 60 DAS. Results revealed that nipping and all growth retardant treatments significantly reduced the plant height (cm) and increased total number of branches, total dry matter production, total leaf area, leaf area index and seed yield compared to control. Among the treatments, foliar application of mepiquat chloride @ 1000 ppm was recorded significantly lower plant height (153.72 cm) and higher total number of branches (37.85 plant^{-1}), total dry matter production (149.12 g plant^{-1}), total leaf area (85.83 dm^2 plant^{-1}), leaf area index (2.384) and seed yield (1970 kg ha^{-1}) as compared to all other treatments. The treatment T_5 (chlormequat chloride @ 1000 ppm) was recorded second best morpho-physiological parameters and yield in pigeonpea. The results concluded that foliar application of mepiquat chloride @ 1000 ppm at 60 DAS was found best in recording better growth parameters and higher yield in pigeonpea.
Keywords: Pigeonpea Crop, Plant growth retardants, *Kharif season*, nipping

INTRODUCTION

Pigeonpea [*Cajanus cajan* L. Millsp] is one of the major grain legumes (pulse) crop of the tropics and subtropics, endowed with several unique characteristics. Pigeonpea also known as redgram or arhar or tur, is the second most significant pulse crop of India after bengalgram. Worldwide, pigeonpea is grown in about 4.9 M ha with a production of 3.65 Mt and productivity of 898 kg ha^{-1}. India is the largest producer of pigeonpea accounting about 82.0 per cent of total production and 81.0 per cent of total area of the world (Anon., 2021). Although, pigeonpea is most important pulse crop of India but yield is very low as compared to world's average. The main constraints for lower yield and low harvest index in pigeonpea are improper translocation of photo assimilates, reduced availability of photo-assimilates at the time of seed set and excessive vegetative growth, which leads to poor productivity. Nowadays nipping practice is done in pigeonpea crop to solve the excessive vegetative growth problem and also to get more yield but it is laborious work as it needs more time and more labours. Hence, this experiment was planned to study the effect of nipping on growth and yield comparing with other treatments like foliar application of different plant growth retardants.

MATERIALS AND METHODS

The field experiment was conducted at Agricultural Research Station, College of agriculture, Bheemarayanagudi during *Kharif* 2021-22. GRG-811 variety was used in experiment. Seeds were sown at spacing of 120 cm between rows and 30 cm between plants at a depth of 5 cm. The experiment was laid out in randomized complete block design and replicated three times with eight treatments including control, nipping at 60 DAS, mepiquat chloride @ 1000 ppm, thiourea @ 1000 ppm, chlormequat chloride @ 1000 ppm, daminozide @ 1250 ppm, ancymidol @ 1000 ppm and paclobutrazol @ 150 ppm were applied through foliar application at 60 DAS. Five plants were selected randomly from each net plot and were tagged for recording various observations. Based on observations recorded on five tagged plants, average values per plant were calculated. Observations on growth parameters were recorded at 100 DAS and yield was calculated after harvest of crop.

RESULTS AND DISCUSSION

Morphological parameters

Plant height

The data recorded on plant height in pigeonpea presented in Table 1. At 100 DAS the significantly higher plant height was recorded in control (177.47 cm) over other treatments except treatment nipping (173.93 cm) which was on par with control. Among the treatments, foliar application of mepiquat chloride @ 1000 ppm was found with lower plant height (153.72 cm), followed by chlormequat chloride @ 1000 ppm (158.35 cm). The treatments daminozide @ 1250 ppm (168.43 cm) and ancymidol @ 10 ppm (167.87 cm) were on par with each other. Basically, plant height is a genetically controlled character, but several studies indicated that plant height can be either increased or decreased by the application of synthetic plant growth regulators. Our results are in line with the results obtained by Gurdeep *et al*. (2020) in green gram; Arora *et al*. (1998) in chickpea; who reported that the growth retardants have specific capability to reduce plant height by reducing internodal length. Among the treatments, foliar application of mepiquat chloride @ 1000 ppm reduced plant height significantly than other treatments as it counteracts the gibberellin biosynthesis which in turn reduces internodal length and further plant height decreased. Similar findings were obtained by Sudharani and Sudhakar (2018) in pigeonpea and Arunakumar and Uppar (2007) in moth bean.

Number of branches plant^{-1}

The data revealed that the treatment mepiquat chloride @ 1000 ppm recorded significantly higher number of branches (37.85plant^{-1}) than other treatments followed by chlormequat chloride @ 1000 ppm (36.21 plant^{-1}) and paclobutrazol @ 150 ppm (35.08 plant^{-1}). The significantly less number of branches (30.24 plant^{-1}) were noticed in control than all other treatments. Our results are in agreement with the results obtained by Sharma *et al*. (2003) in pigeonpea and Grossman (1990) who reported that the anti-gibberellin activity of mepiquat chloride, chlormequat chloride and other growth retardants might have lowered the growth in vertical axis and therefore, growth correlation mechanism could have boosted more axillary growth by elongating the axillary sprouts into branches.

Total dry matter production plant^{-1}

The significantly higher total dry matter production per plant was recorded in treatment mepiquat chloride @ 1000 ppm (149.12 g plant^{-1}) compared to all other treatments. The treatments daminozide @ 1250 ppm (131.94 g plant^{-1}) and ancymidol @ 10 ppm (133.47 g plant^{-1}) were on par with each other. Significantly lower dry matter production per plant was seen in control (119.21 g plant^{-1}). The increase in total dry matter accumulation with growth retardants treated plots might be due to increased photosynthetic efficiency of leaves and also due to the translocation of stored photo-assimilates towards the development of reproductive organs thus, assisting in accumulation of more photosynthates by plants and ultimately resulting in higher dry matter accumulation. Other important reason might be increased stem thickness in shorter plants than taller plants in control, had also contributed to increased dry matter production in growth retardant treatments.

Table 1. Influence of nipping and plant growth retardants on morphological parameters at 100 DAS and yield in pigeonpea

Treatments	Plant height (cm)	Total number of branches	Total dry matter (g plant^{-1})	Total leaf area (dm^2 plant^{-1})	Leaf area index (LAI)	Yield (kg ha^{-1})
T_1 – Control	177.47	30.24	119.21	57.87	1.607	1580.28
T_2 - Nipping at 60 DAS	173.93	31.75	124.50	64.78	1.800	1631.94
T_3 - Mepiquat chloride @ 1000 ppm at 60 DAS	153.72	37.85	149.12	85.83	2.384	1970.00
T_4 - Thiourea @ 1000 ppm at 60 DAS	172.86	32.05	126.73	66.88	1.858	1668.89
T_5 - Chlormequat chloride @ 1000 ppm at 60 DAS	158.35	36.21	143.35	81.29	2.258	1885.00
T_6 - Daminozide (Alar, B-9) @ 1250 ppm at 60 DAS	168.43	33.47	131.94	72.20	2.006	1725.56
T_7 - Ancymidol (A-Rest) @ 10 ppm at 60 DAS	167.87	33.93	133.47	73.23	2.034	1746.94
T_8 - Paclobutrazol @ 150 ppm at 60 DAS	163.32	35.08	138.83	77.14	2.143	1823.06
Mean	166.99	33.82	133.39	72.40	2.005	1753.96
S.Em (±)	1.49	0.35	1.37	0.81	0.023	18.16
C.D at 5%	4.53	1.06	4.17	2.42	0.068	55.07

Our results are similar with the findings of Gangadhara *et al*. (2022) in horse gram and Phulekar *et al*. (1998) in groundnut. The treatment that received foliar application of mepiquat chloride @ 1000 ppm was found superior with significantly higher total leaf area (85.83 dm^2 $plant^{-1}$) than all other treatments in control (57.87 dm^2 $plant^{-1}$) compared to all other treatments. Leaf is the physiological platform for the process of photosynthesis which is the main input of yield. The total leaf area per plant found more in all treatments over the control. Increase in leaf area was due to increased production of secondary branches as influenced by mepiquat chloride and other growth retardant treatments and thus, there will be new growth of a greater number of leaves. Garg *et al*. (2006) in cluster bean and Phulekar *et al*. (1998) in groundnut were also reported the similar results. The significantly highest leaf area index was recorded in treatment mepiquat chloride @ 1000 ppm (2.384) compared to all other treatments and lowest was observed in control (1.607). The enhanced leaf area index in growth retardant treatments could be due to increased efficiency in translocation of stored photosynthates laterally across the plant which resulted in enhanced total leaf area and increased production of both primary and secondary branches. Our results are in line with the findings of Srivastava and Tiwari (1981); Islam and Jahan (2016) in chickpea.

Table 2. Influence of plant growth retardants on biophysical, biochemical parameters at 100 DAS and yield of pigeonpea

Treatments	Photosynthetic rate (µ mol CO_2 m^{-2} s^{-1})	Transpiration rate (m mol H_2O m^{-2} s^{-1})	Total chlorophyll content (mg g^{-1} fresh weight)
T_1 – Control	15.00	4.32	1.470
T_2 - Nipping at 60 DAS	15.59	4.86	1.530
T_3 - Mepiquat chloride @ 1000 ppm at 60 DAS	17.97	6.28	1.996
T_4 - Thiourea @ 1000 ppm at 60 DAS	15.75	5.13	1.586
T_5 - Chlormequat chloride @ 1000 ppm at 60 DAS	17.43	5.95	1.889
T_6 - Daminozide (Alar, B-9) @ 1250 ppm at 60 DAS	16.28	5.37	1.680
T_7 - Ancymidol (A-Rest) @ 10 ppm at 60 DAS	16.43	5.48	1.739
T_8 - Paclobutrazol @ 150 ppm at 60 DAS	16.89	5.71	1.828
Mean	16.42	5.39	1.715
S.Em (±)	0.16	0.06	0.019
C.D at 5%	0.50	0.18	0.057

Biophysical and Biochemical parameters

The data recorded on biophysical, biochemical parameters (Table 2) in pigeonpea. At 100 DAS, there was significant difference between the treatments in photosynthetic rate. The foliar application of mepiquat chloride @ 1000 ppm recorded significantly higher photosynthetic rate (17.97 µ mol CO_2 m^{-2} s^{-1}). Whereas, the lower photosynthetic rate was noticed in control (15.00 µ mol CO_2 m^{-2} s^{-1}), ancymidol @ 10 ppm (16.43 µ mol CO_2 m^{-2} s^{-1}) and paclobutrazol @ 150 ppm (16.89 µ mol CO_2 m^{-2} s^{-1}) were on par with each other. The significantly highest transpiration rate (6.28 m mol H_2O m^{-2} s^{-1}) was noticed in foliar application of mepiquat chloride @ 1000 ppm over all other treatments followed by treatment chlormequat chloride @ 1000 ppm (5.95 m mol H_2O m^{-2} s^{-1}) and the significantly lower transpiration rate was noticed in control (4.32 m mol H_2O m^{-2} s^{-1}).

The photosynthetic rate in all the treatments was found significantly more compared to control, which can be attributed to increased chlorophyll content and increased leaf area index by application of plant growth retardants than control. Similar results were reported by Rajesh *et al*. (2014) in greengram and Karuppusamy *et al*. (2021) in pigeonpea. At 100 DAS, the foliar application of mepiquat chloride @ 1000 ppm was found superior with significantly higher total chlorophyll content (1.996 mg g^{-1} fresh weight) than all other treatments. The significantly lowest total chlorophyll content (1.470 mg g^{-1} fresh weight) was found in control. Similar increase in total chlorophyll content was also reported in sunflower due to application of mepiquat chloride (1000 ppm) by Kulkarni *et al*. (1995). It has also been suggested that the application of growth retardants improved source-sink transport which in turn increased the availability of assimilates *i.e.,* hormone directed translocation of photosynthates, which will cause prolonged chlorophyll synthesis (Stoddart, 1965).

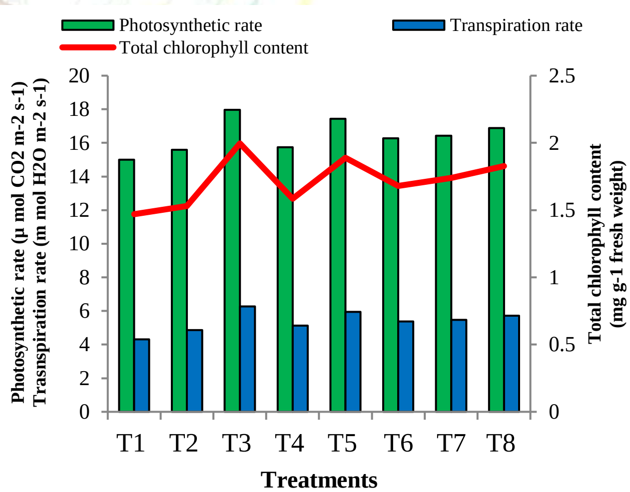

Figure 1. Influence of plant growth retardants on biophysical, biochemical parameters at 100 DAS and yield of pigeonpea

Seed yield (kg ha^{-1})

The data recorded on yield presented in Table 1. The data showed that foliar application of mepiquat chloride @ 1000 ppm was found best with significantly highest seed yield of 1970.00 kg ha^{-1}, which was 24.66 % more than

control followed by treatment chlormequat chloride @ 1000 ppm (1885.00 kg ha^{-1}), paclobutrazol @ 150 ppm (1823.06 kg ha^{-1}) and control recorded significantly lowest seed yield (1580.28 kg ha^{-1}) compared to all other treatments. Similar findings were also reported by Techapinyawat *et al*. (1995) in mung bean, Kalyankar *et al*. (2007) in soybean and Pourmohammad *et al*. (2014) in rapeseed.

CONCLUSIONS

From the results of the present experiment, it can be concluded that foliar application of mepiquat chloride @ 1000 ppm has helped the crop to record significantly higher growth attributes and also in attaining highest potential yield of the crop. The possible reason for the effect of mepiquat chloride maybe, as it is an anti-gibberellin chemical, it inhibited biosynthesis of gibberellin thus, reduced internodal length as well as height of the crop and promoted more lateral growth by increasing number of primary as well as secondary branches. It also significantly improved the source and sink relationship which ultimately helped the crop to attain maximum potential yield.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

Effect of Increasing Phosphorus Doses Application on Some Physical, Chemical and Biological Properties of Soil, Under Long-Term Experiment Conditions.

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ABSTRACT
Phosphorus (P) fertilizers are produced from rock phosphate (apatite); however, they are low-mobility in soil for plant nutrient absorption and uptake. In addition, the rock phosphate quantity is a limited source for future P fertilizer. At the same time, high phosphorus fertilization will cause environmental pollution (such as eutrophication in rivers). Also, a great proportion of applied P fertilizer remains in the soil, reducing the viable soil organisms. Therefore, the effect of different doses of P on some properties of soil (physical, chemical, and biological) is not entirely understood in the literature under long-term experiment conditions. Also, phosphorus fertilizer applications indirectly decrease the plant growth and yield. Under long-term experimental conditions, this research aims to understand the effect of increasing P doses on some physical, chemical and biological properties of the soil. The hypothesis to be tested is that under long-term field experiment conditions, increasing doses of phosphorus fertilizer negatively affect the soil properties. The field experiment was established in 1998 and has continued uninterruptedly to the present time under maize and wheat rotations. Four doses of P fertilizers were applied; such as 0, 50, 100 and 200 kg P_2O_5 ha^{-1} application with three replications. P2105 Maize (*Zea mays* L.) species seeds were sown in June 2022 and harvested in November 2022. At harvest, the soil samples were taken at 0-15 cm and 15-30 cm depth in each plot. Soil pH, EC and available P were analyzed as soil chemical properties. The number of mycorrhizal spores and Soil Organic Matter (by walkley-black method) were determined as soil biological properties. Furthermore, soil bulk density (BD), water stable aggregated (WSA) and mean weight diameter (MWD) were analyzed as soil physical properties.
Phosphorus application in increasing doses negatively affects the soil physical properties (such as WSA, MWD and BD) under long-term field experiment condition. The research finding showed that depending on increasing P doses application soil WSA and MWD were decreased but BD was increased. While depending on increasing P doses application soil organic carbon is increased, however, the numerical value of mycorrhizal spores and root colonization was decreased. The results are revealed that for sustainable and eco-friendly crop production, 50 and 100 kg P_2O_5 ha^{-1} P fertilizer can be used in maize production.
Keywords: Long-term field experiment, Soil organic carbon, Maize plant, Soil MWD, WSA, Phosphorus doses fertilizer

INTRODUCTION

Fertilizer usage is expected to carry on to grow with the growing food needs of the world population (Li et al., 2020). Phosphorus fertilizers are manufactured from rock phosphate (Green, 2015), and it has not a sustainable source and it can be finished next 50-100 years (Schnug & De Kok, 2016). Phosphorus deficiency is the restrictive factor for crop production on 40% of the arable worlds' land (Dey et al., 2021). Insufficient P fertilization leads to crop loss, while excessive P fertilization causes environmental problems such as eutrophication (Frossard et al., 2016). In addition, excessive P fertilization can also cause negative effects on the environment such as P heavy metal pollution (Kilgour et al., 2008) and salinity (Dey et al., 2021). Therefore, optimum P fertilization plays a significant role in protecting the environment as well as improving soil quality and fertility.

Land use has affected soil quality like physical, chemical and biological fertility (Bakhshandeh et al., 2019). Soil realize a significant environmental and ecological facility for food and survival life. In addition, soil health management has key role aimed at conservation of ecological production (Pahalvi et al., 2021). The main role of the soil has into yield enough nourishment and protected human health. Intensive input production such as intensive fertilization, tillage and excessive irrigation have an undesirable impact on soil health. One of them, chemical fertilizer has the greatest important role to

improve soil fertility and yield. There are three types of available mineral(element) fertilizers like; N, P and K fertilizer (Pahalvi et al., 2021). The most used fertilizer after N fertilizers, which include so many potentially harmful chemicals, is P fertilizers. For example, P fertilizers mass-produced from apatite (rock sources) have contaminated by some heavy metals (like Cd, As and etc.) and radio-nuclides (De Kok & Schnug, 2008, Taylor et al., 2016). In addition, it is known chemical fertilizers increase soil salinity (Dey et al., 2021).

Amendment of soil through chemical (such as mineral fertilizers and plant protection preparations) powerfully impacts a variety of some soil properties such as soil activities of enzymes, nutrient content, Organic Carbon, pH, soil moisture and several others features (Prashar & Shah, 2016). Too much use of mineral/chemical fertilizers toughens the soil, lowers fertility of soil, pollutes environment (such as; water, soil and air) and depletes essential minerals and nutrıents out of the soil, thus causing an environmental hazard. The microbial activity in the cropping system is weakened by the use of chemical fertilizers. Continuous use of mineral fertilizers may modification soil pH, rise the chances of pest development, soil acidity and soil crusting, resulting in reduced organic matter, humus load, beneficial organisms, slower plant development, and even greenhouse gas emissions. They definitely affect the biodiversity of the soil, disrupting the well-being of the soil since it has been there for a long time (Pahalvi et al., 2021).

It is known that impact of manure and chemical fertilizers on some quality parameters of soil (Ozlu & Kumar, 2018). However, the impact of increasing P fertilizers, under long-term conditions as field experiment, on some physical, chemical, and biological properties of soil is not clear in the literature. That's why the purpose of the study is to understand the effect of increasing P concentrations on some physical, chemical and biological properties of the soil under long-term experimental conditions. The hypothesis to be tested is that in the long-term field experimental conditions, increasing concentrations of phosphorus fertilizer negatively affect soil properties.

MATERIALS AND METHODS

The field experiment has been established since 1998 on the soil Arık series, which is classified as typical Haploxererts, under maize and wheat rotations. Some physical and chemical properties of Arık soil series shown in Table 1. Four doses of P fertilizers were applied, such as 0, 50, 100, and 200 kg P_2O_5 ha^{-1}, (as P0, P50, P100 and P200), with tree replications before each term. P2105 Maize (*Zea mays* L.) species seeds were sown in June 2022 and harvested in November 2022. At harvest, the soil samples were taken at different depth as surface soil (as 0-15 cm) and subsurface soil (as 15–30 cm) in to each plot.

Soil pH and EC have defined 1:2.5 ratio of distilled water and available P were analyzed by Olsen (1954) method as soil chemical properties. The number of mycorrhizal spores was determined by Gerdemann and Nicolson (1963) and Soil Organic Matter (SOM) was analyzed via Walkley and Black (1934) method as soil biological properties. Furthermore, water stabile aggregate (WSA) and mean weight diameter (MWD) were analyzed by Kemper and Rosenau (1986) and soil bulk density (BD) was defined by Blake and Hartge (1986) as soil physical properties.

ANOVA statistical analysis was realized by JMP 8-pack program and the Less Significant Different (LSD) test was carried out. Moreover, the Origin 2022 application was used for the correlation matrix of variates.

Table 1. Some physical and chemical properties of Arık soil series (Turgut & Koca, 2019)

Soil Properties		Results
pH	(sat.)	7.63
EC	(mmhos cm^{-1})	0.06
Lime	(%)	27.2
Organic Matter	(%)	1.17
Texture (%)	Sand	17
	Silt	28
	Clay	55
Texture Classification	-	C
P_2O_5	(kg da^{-1})	7.11

RESULTS AND DISCUSSION

Soil Physical Properties

It is the physical properties of the soil that affect soil erosion, seed germination and root growth processes. Physical properties cause many chemical as well as biological processes, which can promote controlled by climate, land location, and land management (Jat et al., 2018).

In this work, MWD, WSA, and BD were investigated as physical soil properties. It was shown the impact of increasing doses of P applications on MWD and WSA in Figure 1 and Figure 2. They are shown that there was no statistically difference in MWD 0-15 cm and WSA at different soil depth ($P > 0.05$). Nevertheless, it is shown that statistically significant difference ($P<0.05$) on MWD at 15-30 cm depth as seen in Figure 1 and Table 2. In addition, it was shown that there was a negative correlation (from r = -0.43 to r = -0.83) between soil aggregation and soil available P content at different depths as seen in Figure 7. But on average, depend on increasing P fertilizer application, MWD and WSA are decrease. The P200 application reduced MWD by 26.4% surface soil and by 33.7% at subsurface soil compared to the P0 application. Furthermore, P200 application reduced WSA by 14.7% at 0-15 cm depth and by 14.6% at 15-30 cm compared to the P0 application. Intensive and heavy cultivation (like tillage, fertilizers and irrigation etc.) can disrupt soil aggregates, if those are not protected by the soil organic matter (Ozlu & Kumar, 2018, Ellis, 1971). It can cause a decrease in the WSA

and MWD of the soil with the additives it contains. For example, Ozlu and Kumar (2018) reported that heavy chemical fertilizer application had lower aggregation (MWD and WSA) than control (without fertilizer) and organic fertilizers. Işık et al. (2019) investigated the impact of different organic and inorganic fertilizer applications on soil aggregation under long-term conditions. It seems that chemical fertilizers have the lowest aggregation and it was supports our research findings. Haynes and Naidu (1998) observed that continual application of inorganic fertilizer can diminish aggregate formation and stability by dispersing colloids and secondary soil particles and these findings lend credence to our investigation. Chemical fertilizers like TSP, which comprise additives, contain elements including Al, Ca, Fe, K, Na, Si, and high salinity (Shahsavani et al., 2017). In particular, Na can limit soil aggregation (García-Orenes et al., 2005).

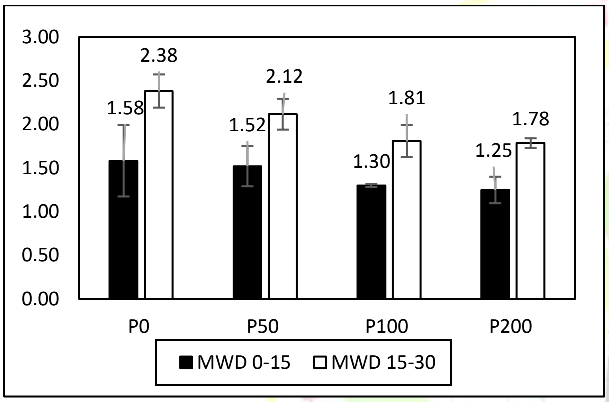

Figure 1. Effect of increasing phosphorus doses application on MWD in different depth.

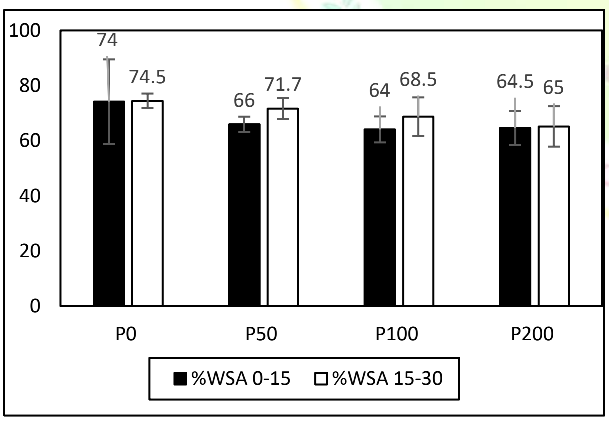

Figure 2. Effect of increasing phosphorus doses application on WSA (%) in different depth.

BD can be defined as the relationship between mass and volume of soil (de Oliveira et al., 2015) and it is usually expressed in g/cm^3. Typical values of the dry or BD of most soil differ between 1.1 and 1.6 g cm^3 (Rai et al., 2017). Soil BD determines the soil's porosity, available water capacity, infiltration, nutrient availability, rooting depth, root spread and microorganism activity (Indoria et al., 2020). Therefore, BD has an important place among soil physical properties. it was showed the effect of increasing phosphorus doses on BD in Figure 3. Increasing doses of P fertilization was not statistically make a difference (P>0.05) in soil BD, but it did increase the BD on average, under long term conditions. Moreover, it is shown that there was a statistically positive correlation (r = 0.83 and 0.58) between soil available P and BD in Figure 7. It has means that increasing doses of P fertilizers also increase soil BD.

Guo et al. (2016) research findings from their studies conducted between 2009 and 2014 show that chemical fertilizer applications increase BD compared to organic fertilizer applications. Their study partially supports our research findings. Moreover, Figure 3 shows that subsurface soil had a higher BD than surface soil depth. The decrease in BD over the years might be due to the increase in plant biomass, root biomass, the cementing effect of organic polysaccharides formed by the decomposition of OM through microbial activity. Pant and Ram (2018) reported that BD showed an increasing trend with increasing soil depth under respective treatments, and soil BD was lower in balanced and optimal fertilization treatments.

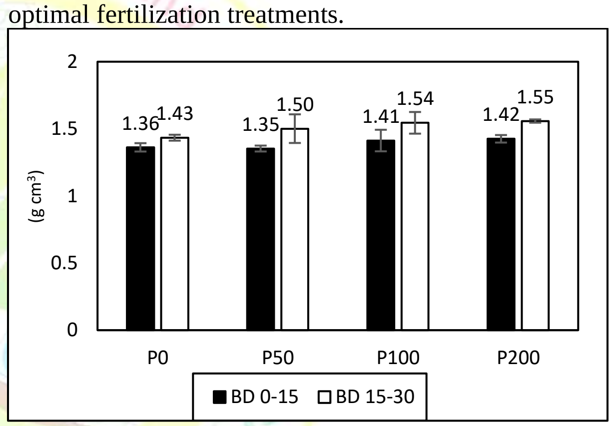

Figure 3. Effect of increasing phosphorus doses application on BD in different depth.

Table 2. Level of significance for effects of increasing phosphorus doses application on MWD, WSA, BD, P_2O_5, pH, EC, Organic Matter (O.M) and number of Mycorrhizal Spores (M. Spores) in different soil depth (0-15cm and 15-30cm)

MWD 0-15	**MWD 15-30**	**WSA 0-15**	**WSA 15-30**	**BD 0-15**	**BD 15-30**
NS	*	NS	NS	NS	NS
P_2O_5 0-15	P_2O_5 15-30	pH 0-15	pH 15-30	EC 0-15	EC 15-30
**	***	NS	NS	NS	NS
O.M 0-15	O.M 15-30	M. Spores 0-15	M. Spores 15-30		
NS	**	NS	NS		

NS means not significant. *, ** and *** respectively show significant level at P ≤ 0.05, P ≤ 0.01 and P ≤ 0.001.

Soil Chemical Properties

Soil chemical properties are essential to plant nutrition. Soil chemical properties were pH, TC, TN, cation exchangeable capacity (like Ca, Mg, K and Na),

available P (Ahmadpour et al., 2015). One of them, P, is a factor that negatively affects 40% of agricultural production due to its deficiency (Balemi & Negisho, 2012). Inadequate P fertilization can lead to crop losses, whereas too much P fertilization can causes environmental problems such as eutrophication (Frossard et al., 2016). For that reason, optimum P doses fertilizers is vital for economic, sustainable and eco-friendly plant production.

It is presented that the impact of increasing P doses on soil available P at different depth as seen Figure 4. Increasing doses of P fertilization made a statistically significant difference (at surface soil P<0.01 and at subsurface soil P<0.001) at both depths as seen in Table 2. It is expected that the soil available P concentration will increase depending on the application of increasing doses of P. There are so many studies about how the soil P concentration will increase depending on increasing doses of P (Akpinar & Ortas, 2023, Işık et al., 2020a, Zhang et al., 2004). Additionally, available P concentration in soil surface is greater than subsurface soil. The higher P content of the surface soil than the subsurface may be the result of stubble west (like root etc.) or P fertilizer application close to the surface.

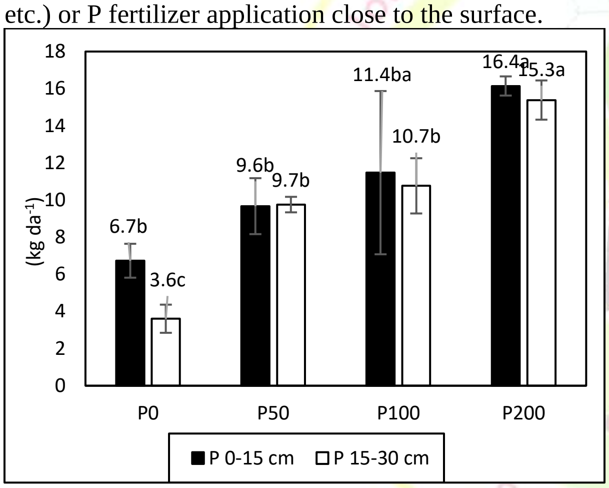

Figure 4. Effect of increasing phosphorus doses application on soil available P in different depth

Soil pH has an important impact on microbial activity and the biogeochemical processes where they participate. In general, the fungal community has an ideal environment in acidic conditions, whereas the bacterial community has decreased, thus the processes accomplish by some microorganisms can be negatively affected (de Melo et al., 2018). Furthermore, soil pH has also effected the nutrition (like Zn, Fe, P and others) uptake (Kacar & Katkat, 2015). It was seen that impact of various phosphorus doses application on soil pH and EC in Table 3. In Table 3, there was no statistical significant different (P>0.05) as soil pH in different depth. rSoil pH was not one of the easily changeable properties of the soil (Özbek et al., 1993). Also, there was no statistical significant different (P>0.05) as soil EC in different depth at Table 3. However, depend on increasing dose P fertilizers also soil EC increase on average. Chemical fertilizer application can cause the soil EC to increase (Citak & Sonmez, 2011).

Table 3. Effect of increasing phosphorus doses application on soil pH and EC (µS cm^{-1}) in different depth.

Applications	pH 0-15 cm	pH 15-30 cm	EC 0-15 cm	EC 15-30 cm
P0	7.65±0.3	7.62±0.0	244±8	187±12
P50	7.51±0.2	7.62±0.1	243±3	197±1
P100	7.60±0.3	7.58±0.0	247±35	201±28
P200	7.56±0.1	7.59±0.1	264±18	202±0
	P>0.05	*P>0.05*	*P>0.05*	*P>0.05*

Soil Biological Properties

Mycorrhizae are a nearly worldwide terrestrial mutualism between plant roots and certain fungi of soil, the oldest fossil evidence about mycorrhiza nearly 400 My ago (Egerton-Warburton et al., 2005). Several study reports revealed that mycorrhizal fungi may increase water and nutrient absorption in addition to increasing the bioavailability of phosphorus (P) to the host plant and improving growth. For the purpose of improved physical, chemical, and biological properties of soils, plant and mycorrhizal interaction is an essential association within rhizosphere (Johnson & Jansa, 2017). It is shown that effect of increasing P doses on the mycorrhizal number of spores in different depth in Figure 5. There weren't significant differences in the impact of increasing quantities of P application on the amount of spores. In addition, there was a negative correlation (r = -0.61 and -0.33) between mycorrhizal spores and soil available P concentration in different depths as seen in Figure 7. Higher amount of P in the plant tissue decreases the number of spores production and secondary external hyphae (Grant et al., 2005). Furthermore, soil pH can negatively affect the number of spores (Qin et al., 2020). It is known that fungi (like mycorrhiza) can usually live at low pH (Davison et al., 2021).

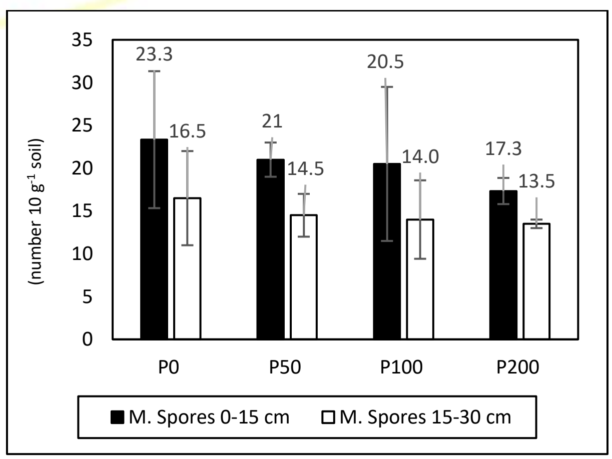

Figure 5. Effect of increasing phosphorus doses application on mycorrhizal number of spores in different depth

organic fraction (Bernoux & Cerri, 2005). Soil OM has a vital role for soil production, fertility and the carbon cycle (Simpson & Simpson, 2017), and it also improves infiltration, porosity, nutrition, and microbial activity (Güzel et al., 2002, Özbek et al., 1993). It was presented that effect of increasing P doses application on soil organic matter (%) in Figure 6. There was no statistical difference at surface soil (P>0.05) nonetheless, there was statistical significant different at subsurface soil (P<0.01) as seen Table 2. Average OM increases with increasing doses of P. The P200 dose has the highest OM ratio (%) compared to P0. The P200 application increased soil OM content by 11.7% at 0-15 cm depth and by 11.9% at 15-30 cm depth compared to P0 application. In addition, it is shown that positive correlation in the middle of available P and OM in different depths (Figure 7). Stubble residues (He et al., 2015), microbial activity and root secretions (like alcohol, enzyme activity, and phenol compounds) may have increased soil OM (Van Aken, 2011, Işık et al., 2020b). In addition, there is a positive correlation among soil P concentration and subsoil %OM in Figure 7.

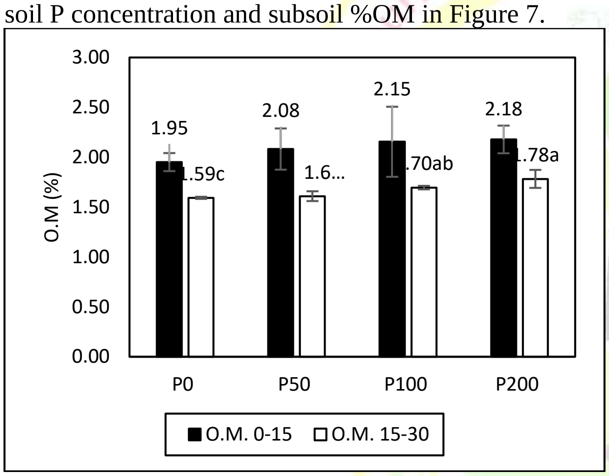

Figure 6. Effect of increasing phosphorus doses application on soil organic matter in different depth

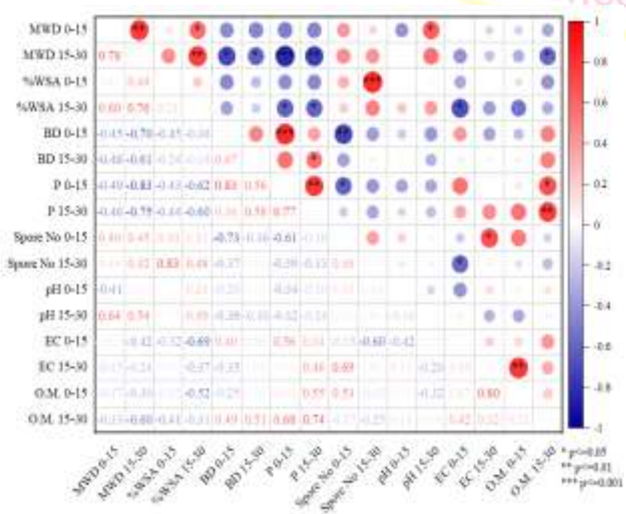

Figure 7. Correlation matrix of soil variates.

CONCLUSION

The physical qualities of the soil (such as MWD, WSA, and BD) were negatively impacted by P fertilization at escalating doses under long-term experiment circumstances initially. Mycorrhizal spore counts were reduced and OM was enhanced as P fertilizer treatment doses were raised. While soil pH and EC characteristics remained mostly unchanged, soil P content increased as P doses were raised. The health of the soil and sustainable production are not improved by excessive chemical P fertilization, which can also have a destructive effect on the soil physical and partially biological qualities.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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Research Article

The Effect of Different Mycorrhizal Fungi Inoculation and Biochar Application on the Growth of Broad Bean Plant and Carbon Sequestration under Different Irrigation Levels.

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ABSTRACT

The experiment was carried out in a total of 54 pots, with 3 replications according to the randomized plot trial design. In the experiment, broad bean (Vicia faba) plant seeds were planted as plant material. In the experiment, 3 irrigation levels were determined for restricted irrigation (50%, 75%, 100% of the field capacity), 3 levels were determined for mycorrhizal fungus (non-mycorrhizal, *G. mosseae* and indigenous mycorrhiza), and for biochar treatments, control and 1% biochar were implemented. As a result of the experiment, carbon analyzes of soil and plant samples were carried out. The data obtained in the study were determined to develop better at 100% irrigation level under the conditions of biochar and G. mosseae inoculation. Carbon and nitrogen values were higher in bean plants in pots inoculated with mycorrhiza and treated with biochar. These results imply that increased soil and plant performance under restricted irrigation conditions can result from the application of biochar and irrigation at level I100.
Keywords: Carbon, mycorrhiza, biochar, bean plant, water use efficiency

INTRODUCTION

The world population was 250 million in the 1000's, it increased to 6.1 billion in 2000 and it is expected to be 9.8 billion by 2050 (Kopittke et al., 2019). In response to population growth, the demand for food is expected to double, and the consumption of drinking water and agricultural irrigation water is expected to increase. In addition, the increasing world population day by day has a significant impact on soils ability to provide the amount of food necessary for human nutrition (Akşahin et al., 2019). As a renewable natural resource, water ranks first among the strategic resources in the world in the 21st century. In addition, increasing drought and very large water scarcity will make the sharing and management of water resources more problematic (Çakmak and Gökalp, 2013) Food security and water sustainability in arid and semi-arid regions are under threat due to rapid population growth, declining natural resources, and global climate change (Abdullah et al., 2022). In general, agricultural irrigation and production consume 70-75% of freshwater resources. It is extremely important to use the water used for agriculture in a more convenient and sustainable way. In light of this information, several plants depend on the correct management of water and soil in order to use the water more efficiently.

In order to maintain adequate water supply in the future for countries like Turkey, which are on the border of water scarcity, it is extremely important to activate the natural mechanisms of plants in the axis of water management and to correctly determine the existing natural plant mechanisms to plan plant production under moisture stress conditions, taking into account the soil-water-plant relationship. Many parameters should be considered in determining plant, water, and soil management. It is extremely important that some of these parameters be determined by the performance of the plants under limited irrigation conditions and to establish positive relations with soil microorganisms. Choosing plants known for their relationship with soil microorganisms is important for both saving water and providing a suitable environment for the plant.

The importance of water is not the only factor that the increase in carbon dioxide equivalent gases in the atmosphere has an impact on at the global scale. It is extremely important that part of these increasing changes arising from agriculture is brought back to agricultural lands. In light of this information, it is extremely important to investigate ways to add carbon to soils.

In addition to keeping water in the soil and keeping it ready for the plant, biochar, which provides a good plant nutrient for plants, is among the subjects that have been studied frequently recently. Lehmann (2009) defines biochar as a material produced by the pyrolysis of organic materials at relatively low temperatures (<700°C) with a limited amount of oxygen. The pyrolysis process, on the other hand, is defined as the thermo-chemical decomposition of organic matter at high temperatures in an oxygen-free environment.

Materials rich in carbon content obtained by heating very different and diverse biomass in an oxygen-free environment are defined as biochar. Biochar is also used differently from non-organic but charred material since it expresses a biological origin.

Known for their nitrogen fixation and significant mycorrhizal dependence within these relationships, broad bean crops can increase soil fertility and conserve water in the arid and semi-arid climatic regions of the Middle East. Due to the symbiotic relationship, the pod has a mechanism to use soil water efficiently.

Under stress conditions, rhizosphere unity, especially native mycorrhizae and plant roots, is significantly important for water uptake.

In light of this information, it was aimed to understand how the bean plant affects soil and plant carbon sequestration in the presence of mycorrhiza under limited irrigation conditions and biochar applications during the establishment of the experiment.

The hypothesis of the study is that mycorrhiza and biochar application under limited irrigation conditions will have a positive effect on the growth of the bean plant and will save irrigation water, and also that the carbon uptake of the plant will increase, and the amount of soil carbon retained in the soil will increase.

MATERIALS AND METHODS

The study was started on February 10, 2022, in the research greenhouses of Çukurova University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, and was completed on April 16, 2020.

The effect of different mycorrhizal fungi inoculation (control, indigenous and selected inoculum (*G. mosseae*)) and biochar application (0 and 1%), and three irrigation levels (50%, 75%, 100% of field capacity) was studied under greenhouse conditions as a pot experiment. For the biochar material, the material that emerged after the maize residues were exposed to the pyrolysis process at 500 degrees was used. The experiment was designed according to a 3-factor randomized plot design.

In order to prepare the soils for analysis after harvest, the soil samples were dried at room temperature (~25 0C) for 15 days and passed through a 2 mm sieve. Determined soil analyzes of the sieved soil by Güzel et al. (1990). At the end of the experiment, the shoot and the root were harvested together and dried in an oven at 70 °. Then, the green parts and root dry weights of the plants were taken, and the green parts were ground and made ready for analysis. K, P and Zn contents of homogenized samples were determined by using an inductively coupled plasma optical emission spectrometry (ICP-OES) device in the extracts obtained by dry burning method. (Kacar and İnal, 2008) Carbon and nitrogen analyzes of soil and plant samples were made with the help of the Fisher-2000 CN analyzer. In order to determine the organic carbon content of the soil samples, the process of subtracting the amount of inorganic carbon in the lime from the total carbon was used. (OC = TC–IC.) Lime analysis was performed with the aid of Scheibler calcimeter (Ülgen and Yurtsever, 1995).

Different package programs were used for the statistical processing of the data of the study. All data were analyzed by a three-way analysis of variance (ANOVA). The smallest differences were made with the Tukey test. The Principal Component Analysis (PCA) of the data was performed with the help of the Excel Stat-14 package program. The Origin pro 20-package program was used for the correlation analysis of the study. Applying biochar to the soil, determining the field capacity, and measuring and supplementing the missing water are given in Figure 1. An image of the trial plant is given in Figure 2.

Figure 1. Applying biochar to the soil, determining the field capacity, measuring, and supplementing the missing water.

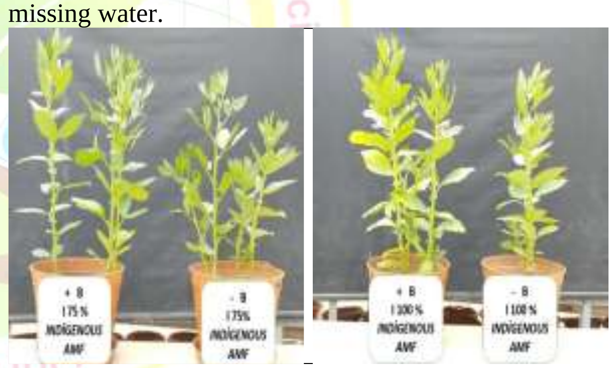

Figure 2. An image of the experiment

RESULTS AND DISCUSSION

Tendency of Carbon and Nitrogen in Soil under Restricted İrrigation Conditions

The differences in the percentages of organic carbon (OC) and nitrogen (N) formed in the soil as a result of biochar and mycorrhiza added to the soil under limited irrigation conditions applied at different levels are given in Figure 3.

When the data obtained were examined, it was concluded that the triple of restricted irrigation (I), Biochar (B) and Mycorrhiza did not form a statistical interaction in the OC % and N% values of the soil.

When the OC values of the soil were analyzed, according to the results obtained, the highest OC% value was obtained as 0.54 % in +B*I75* *G. mosseae* applications, while the lowest OC% value was obtained in -B*I50*Control applications as 0.22 %.

When the N values of the soil were examined, the highest N% value was obtained as 0.092% in +B*I50*Control applications, while the lowest N% value was obtained as 0.044% in -B*I75*Control applications.

C/N values calculated according to the results obtained in the study are given in Figure 4. The effect of the triple interaction on C/N values was not statistically significant. When the results were examined, the highest C/N value was 7.22 in the +B*I100*Control application, while the lowest C/N value was 4.28 in the -B*I50*Control application. According to the results obtained, it is seen that the biochar applied to the soil increases the C/N value of the soil.

Ortas et al. (2013) reported that Organic matter applications applied to the soil increased the OC, N % and C:N parameters compared to the control. The literature information given supports the data obtained as a result of the application of biochar in the study. In general, the average C:N ratios of soils range from 9.9 for arid soils to 25.8 for Histosol soils. (Batjes, 1996). Because the soil employed in our study was poor soil and located in a dry environment, the value of C/N fell between 4.28 and 7.22. According to Jabborova et al. (2022) investigated the effects of biochar and mycorrhiza on the growth of soybean plants and against drought in their study under limited irrigation conditions. As a result of the examination, it was reported that the dual applications of AMF and biochar had a positive effect on 28.3% of microbial biomass compared to the control, the number of AMF spores, and several other parameters in drought conditions.

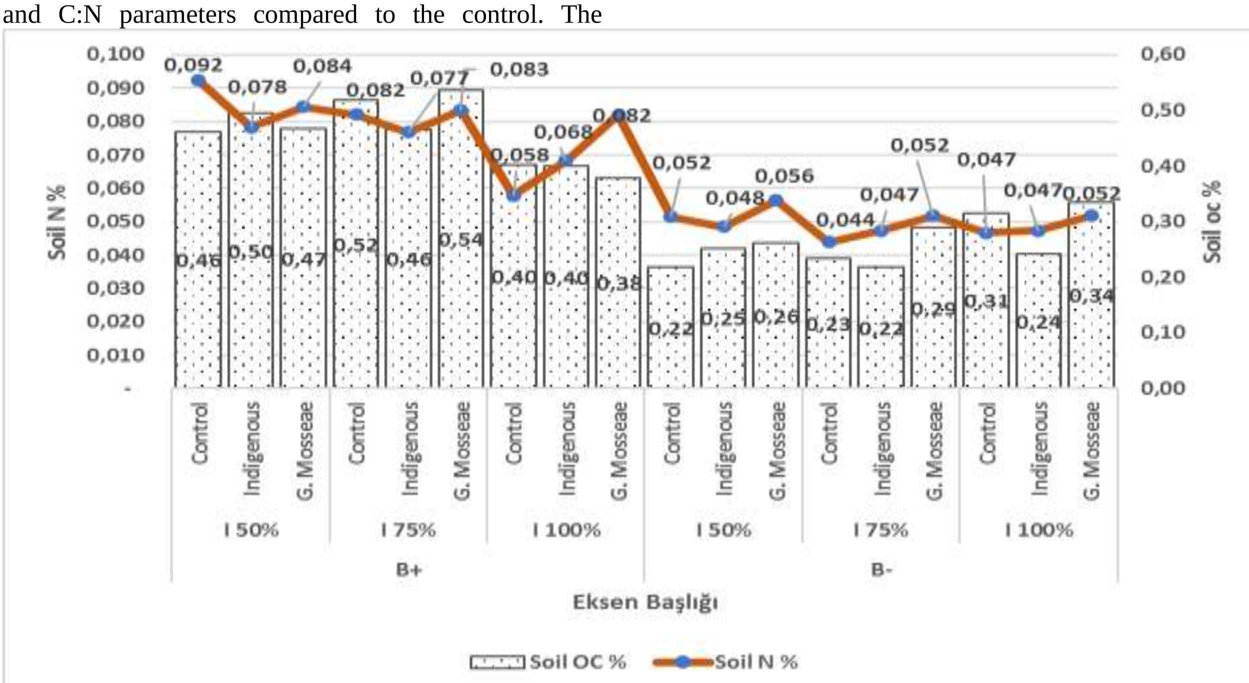

Figure 3. Effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on soil OC and N

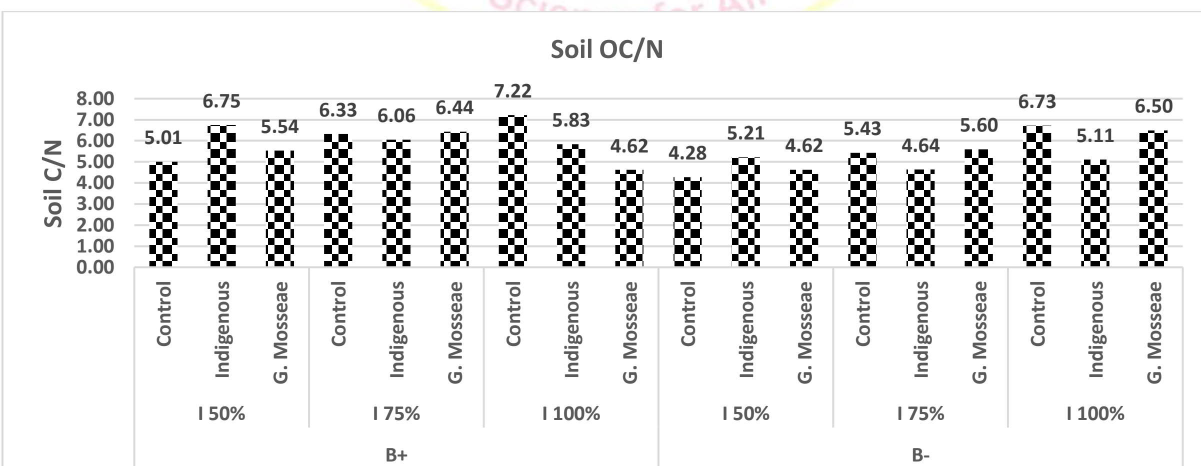

Figure 4. The effect of biochar and mycorrhiza applied to the soil under restricted irrigation conditions on the C/N of the soil.

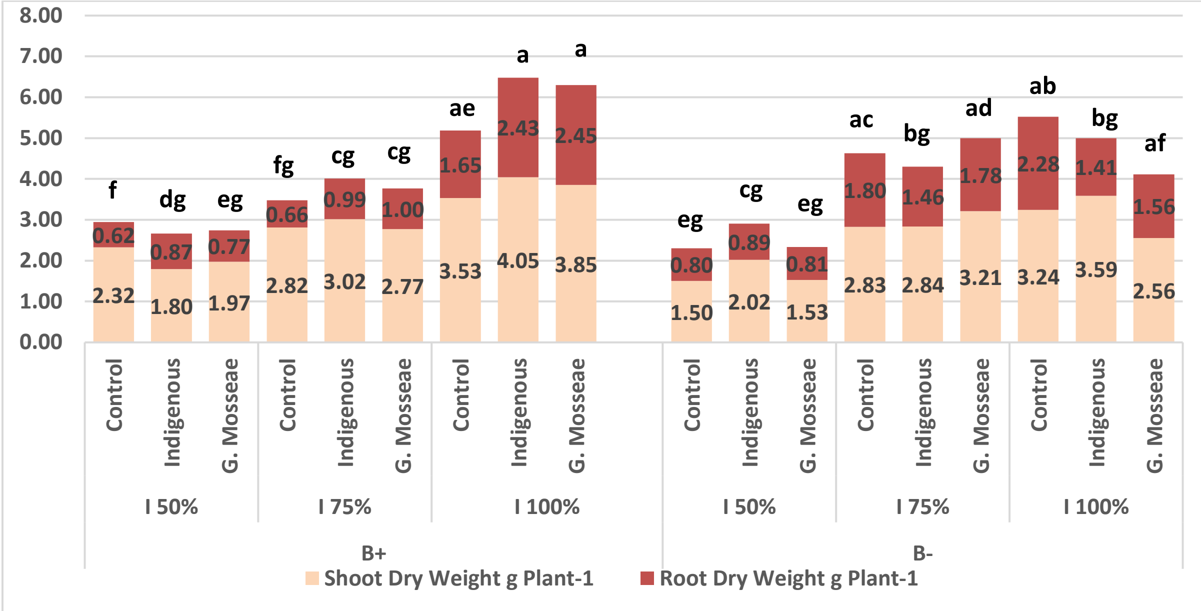

Figure 5. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot dry weight of the plant. *(The letterings are given for the dry weight values of the plant root and the differences are revealed by the tukey test.).*

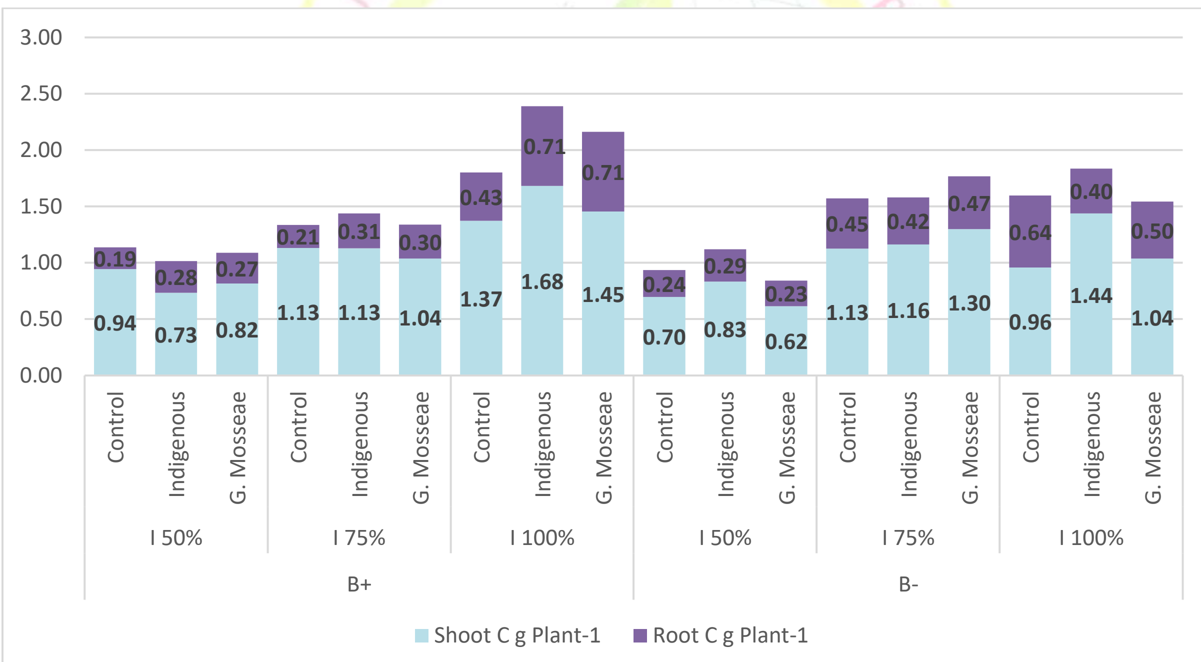

Figure 6. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot C content of the plant.

The Effect of Biochar and Mycorrhiza Applied Under Limited İrrigation Conditions on The Dry Weight of The Plant.

The root and shoot dry weight values of the broad bean plant grown in the area where biochar and mycorrhiza inoculation were added to the soil under limited irrigation conditions applied at different levels are given in the Figure 5.

According to the results obtained, it is seen that there is a triple B*I*M interaction on root dry weight values of the broad bean plants and this interaction is seen to be statistically significant, while its effect on shoot values is not statistically significant.

When the root values of the broad bean plant are examined, the highest root dry weight value was obtained as 2.45 g plant^{-1} in the +B*I100*G.Mosseae application, while the lowest root dry weight value was obtained as 0.62 g plant^{-1} in the +B*I50*Control application.

When the shoot values of the broad bean plant were examined, the highest shoot dry weight value was obtained as 4.05 g plant^{-1} in the +B*I100* *G. mosseae*

application, while the lowest shoot value was obtained as 1.50 g plant^{-1} in the -B*I50*Control application.

According to Sobhani et al. (2022) studied biochar, mycorrhiza, and different nitrogen dollars in their study and reported that 4 tons/ha biochar, 100 kg N/ha application, and AMF inoculation had a beneficial and effective role in increasing the growth and yield of wheat.

The Effect of Biochar and Mycorrhiza Applied Under Restricted Irrigation Conditions on Carbon and Nitrogen Content of The Plant.

Root and shoot carbon values of the broad bean plant grown in the area where biochar and mycorrhiza inoculation were added to the soil under limited irrigation conditions applied at different levels are given in Figure 6, and nitrogen values are given in Figure 7. When the carbon and nitrogen contents of the broad bean plant are examined, it is seen that the triple interaction does not have a statistically significant effect on the root and shoot values.

When root and shoot carbon contents are examined, it is seen that the highest root and shoot carbon content values are 0.71 C g plant^{-1} and 1.68 C g plant^{-1}, respectively, in +B*I100*Indigenous pots, while the lowest root and shoot carbon values are 0.19 C g. plant^{-1} and 0.62 C g plant^{-1} were obtained in +B*I50*Control and -B*I50* *G. mosseae* applications, respectively. When root and shoot nitrogen contents are examined, it is seen that the highest root and shoot nitrogen content values are 0.05 N g plant^{-1} and 0.1 N g plant^{-1}, respectively, in +B*I100*Indigenous pots, while the lowest root and shoot nitrogen content values are respectively. It is seen that it is in the pot of -B*I150*G.Mosseae as 0.02 N g plant^{-1} and 0.05 N g plant^{-1}.

In +B*I100*Indigenous pots, where root and shoot nitrogen contents were tested, the maximum root and shoot nitrogen content values were 0.05 N g plant^{-1} and 0.1 N g plant^{-1}, respectively, while the lowest root and shoot nitrogen content values were. It can be seen that there are two plants in the pot of -B*I150**G. mosseae*, each weighing 0.02 and 0.05 g.

According to Wen et al. (2022) , mycorrhizal colonization rate exhibited a significant positive correlation with soil nutrient availability, including phosphorus, potassium, microbial carbon, and nitrogen. As a result, the growth in plant nutrient accumulation was brought on by the interaction of biochar and AMF with mycorrhizal colonization. Zhao et al. (2022) investigated how nitrogen, mycorrhiza, and biochar affected the growth of crowgrass and found that biochar greatly boosted the mycorrhizal colonization rate.

The Effect of Biochar and Mycorrhiza Applied Under Restricted Irrigation Conditions on P, K and Zn Content of the Plant.

Figure 8 shows the wide bean plant's root and shoot phosphorus (P) levels. Figures 9 and 10 show the plant's potassium (K) and zinc (Zn) contents. Using the collected data, it was determined that the root P content of the broad bean plant ranged from 1.52 mg plant^{-1} in the +B*I75**G. mosseae* pot to 2.88 mg plant^{-1} in the +B*I100**G. mosseae* inoculated pots. The maximum shoot P value was found to be 4.71 mg plant^{-1} in the +B*I100*Control pot, and the lowest shoot p content was found to be 3.12 mg plant^{-1} in the -B*I50*Control pot when the p contents of the broad bean plant's shoot values were analyzed.

According to the data obtained, the differences resulting from the effect of triple interaction on the root K contents of the broad bean plant were found to be statistically

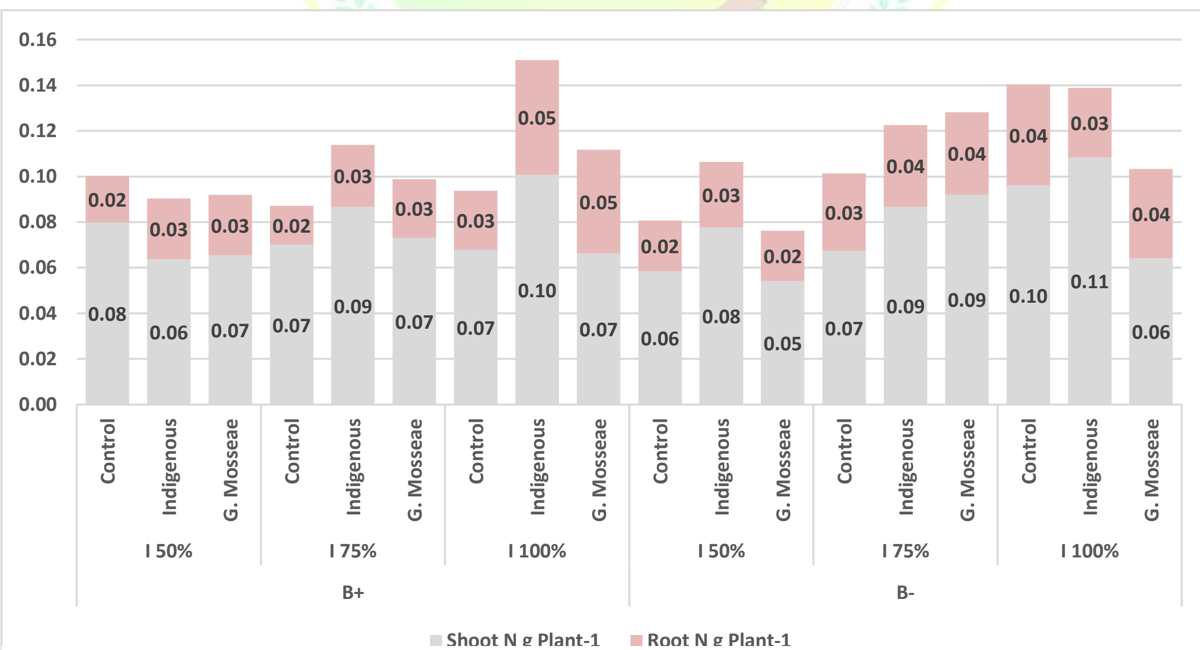

Figure 7. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot N content of the plant.

significant. The highest root K content was obtained as 47.3 mg plant-1 in a +B*I100*Indigenous pot, while the lowest root K content was obtained as 6.5 mg plant-1 in -B*I50*Control pot. When the k contents of the shoot values of the broad bean plant were examined, the highest shoot k value was 105.4 mg plant^{-1} +B*I100*G. While it was obtained in Mosseae pot, the lowest shoot k content was obtained as 35.9 mg plant-1 in -B*I50*Control pot.

According to the data obtained, the highest Zn content for the root and shoot contents of the broad bean plant was 39.6 and 121 µg plant-1 in +B*I100*G.Mosseae pot, while the lowest root and shoot Zn content was 11.1 µg plant-1 and 44.8 µg. plant-1 was also obtained in a-B*I50*Control and -B*I50*G. *mosseae* pots, respectively.

Sun et al. (2022) discovered that maize plants were grown in pots treated with biochar and AMFs, either separately or together, and that individual applications of either biochar or AMFs determined maize growth and mineral contents (P, K, Ca, Na, Mg, Fe, Mn, and Zn). They came to the conclusion that the application of biochar and AMFs can affect maize growth, nutrient uptake, and physiological properties.

particularly in the roots and shoots, are positively correlated. Additionally, there is a favorable correlation between the shot carbon content and the P, K, and Zn contents of the plant.

The Principal Component Analysis (PCA) prgram produced values are given in Figure 12, and the eigenvalue values and KMO analysis are given in Table 1. Field (2000) stated that the lower limit for the KMO test is 0.50 and that the KMO test results above this limit value are suitable for principal component analysis of the data considered to be evaluated. Since our obtained KMO value is 0.6245, it is seen that the data are suitable for PCA.

In order to ascertain the correlations between applications and parameters, the data collected as a consequence of mycorrhiza and biochar applications inoculated into pots with varying irrigation levels underwent Principal Component Analysis (PCA). Figure 12 displays the PCA analysis's outcome. The F1 value changed by 51.95 percent and the F2 value by 18.78 percent when the effects of mycorrhiza and biochar treatments inoculated into the pots with various watering levels are evaluated. Since the resultant F1+F2 value is greater than 60% (70.76%), it can be shown that the PCA

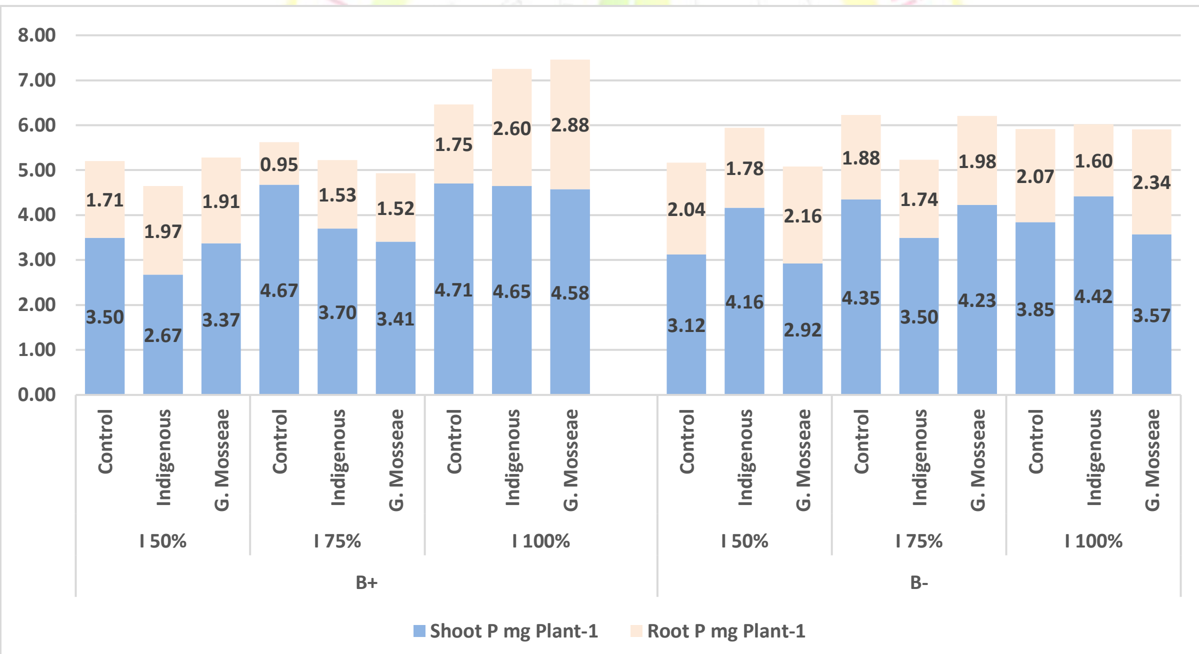

Figure 8. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot P content of the plant.

Correlation And PCA of Data Obtained As A Result Of Different Irrigation Levels, Biochar And Mycorrhiza Applications

Figure 11 displays the findings of the correlation analysis conducted using the obtained parameters. The dry weight of the bikini is positively correlated with several parameters, and these connections are strong, when the data acquired as a result of varying irrigation levels, charcoal applications, and mycorrhiza applications are evaluated. The plant's dry weight and its carbon content,

analysis produced a good explanation for the data. When the eigenvalue values are examined, it is seen that they are above 1 for all F values.

When the results obtained are examined, it is seen that more data are clustered in areas where irrigation is 100% and 75% and there is a positive relationship. It is seen that biochar gives better results in pots with full irrigation than with limited irrigation, and the data are clustered in this area.

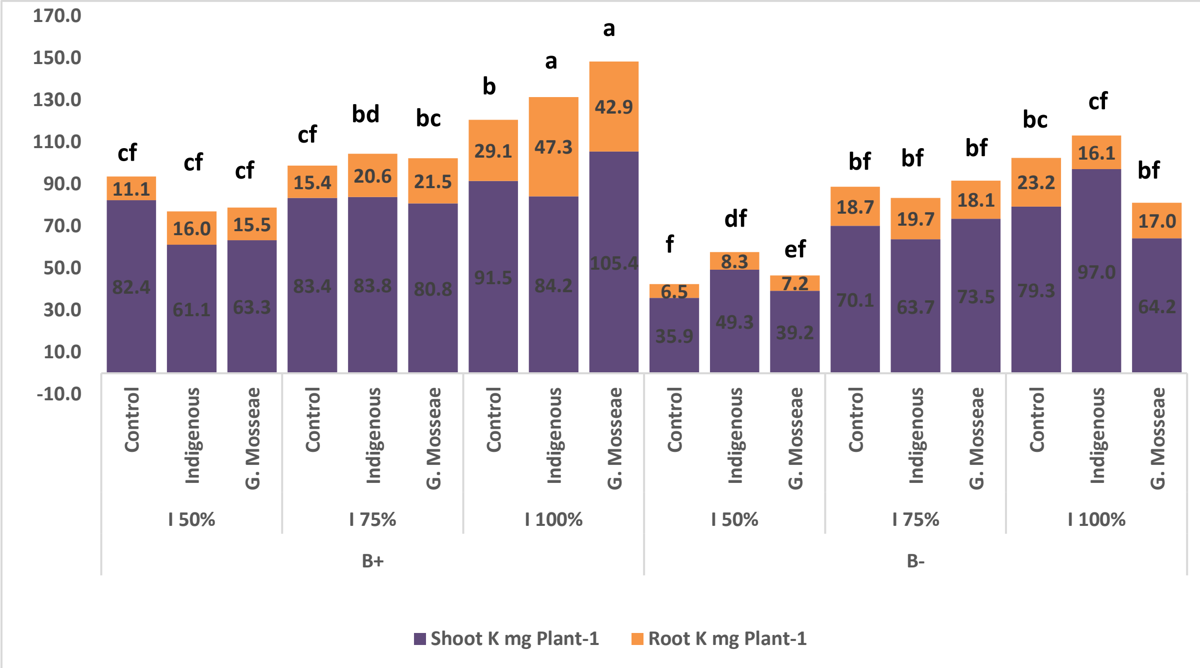

Figure 9. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot K content of the plant. (Letterings are given for Root K values and differences between letters are obtained by Tukey test.)

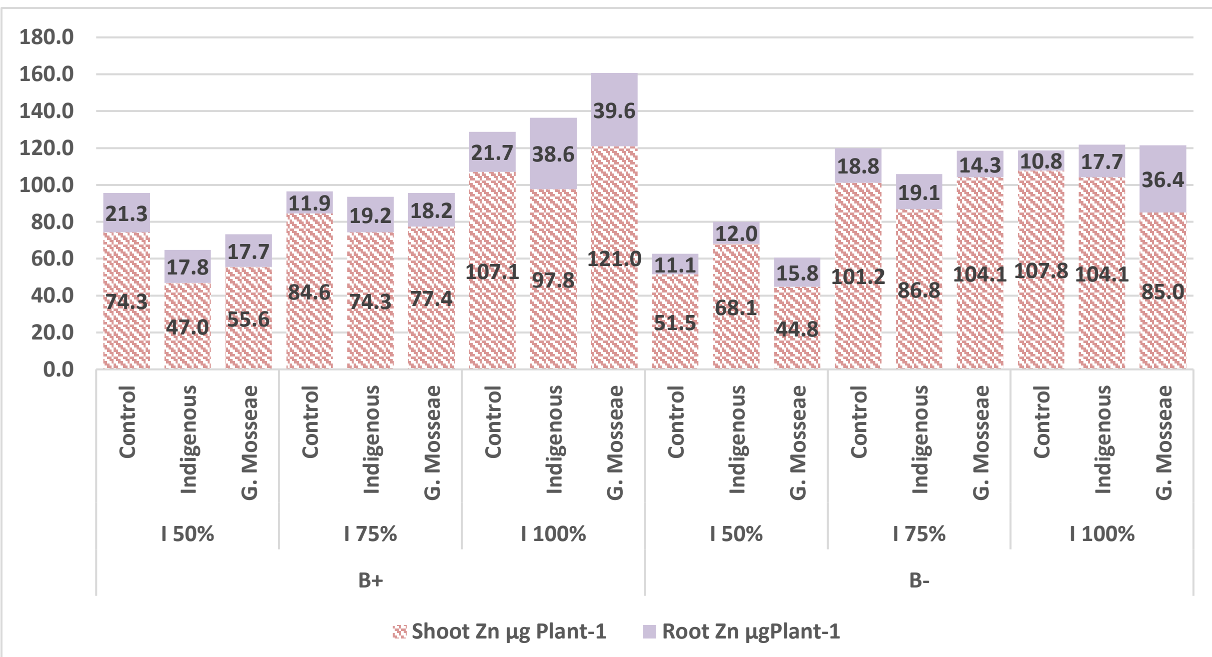

Figure 10. The effect of biochar and mycorrhiza applied to soil under restricted irrigation conditions on Root and shoot Zn content of the plant.

Table 1. Eigenvalue values and the value obtained as a result of KMO analysis

	F1	F2
Eigenvalue	7,7969	2,8170
Variability (%)	51,9791	18,7797
Cumulative %	51,9791	70,7588
Kaiser-Meyer-Olkin measure of sampling adequacy (KMO)	0,6245	

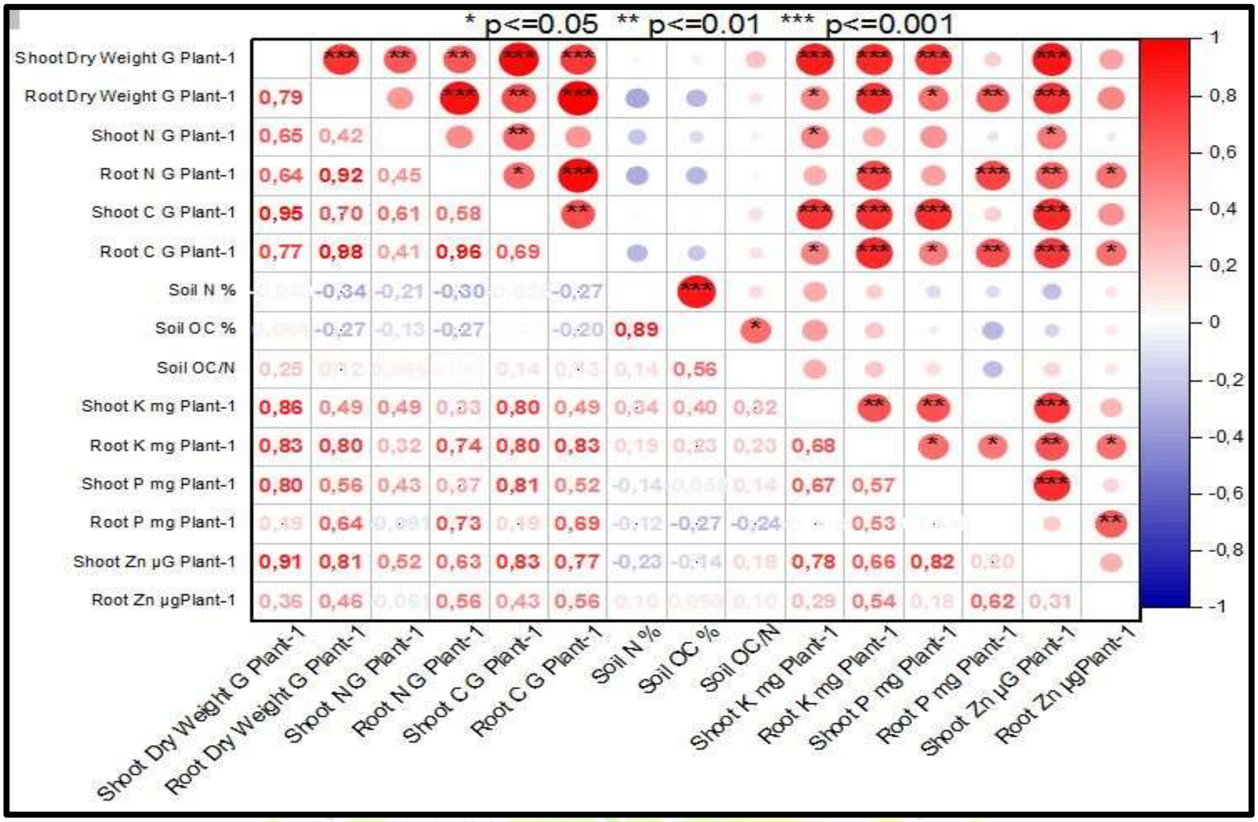

Figure 11. Correlation of The Parameters Obtained As A Result of Biochar and Mycorrhiza Applied To The Soil Under Limited Irrigation Conditions

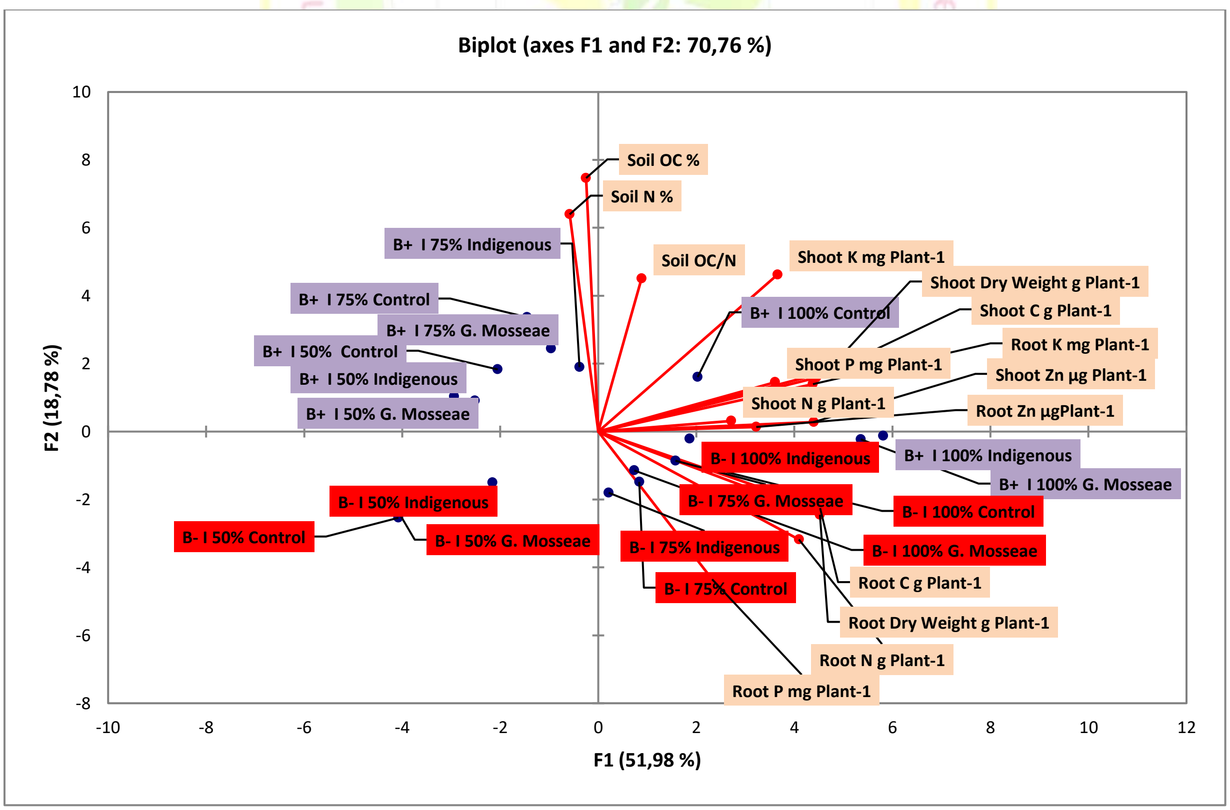

Figure 12. Principal Component Analysis (PCA) analysis of the obtained values.

CONCLUSIONS

The study concluded that the greatest results in terms of soil and plant characteristics were obtained when biochar was applied along with irrigation at a level of I100. The greatest soil organic carbon (OC%) values were obtanied with those treated with both biochar and mycorrhiza (*G. mosseae*). The soil organic carbon to nitrogen (OC/N) ratio was highest in the biochar-equipped pot with full irrigation (I100). The best results were obtained in pots where biochar was applied together with full irrigation, despite the fact that mycorrhizae showed variances in all parameters when taking into account plant parameters (I100). Based on the study's findings, it is evident that the biochar application and I100 level produce the best outcomes.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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